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(PROFESSIONAL PAPER.)

POTASH SALTS AND OTHER SALINES IN THE GREAT BASIN REGION.[1]

By G. J. Young.

GEOCHEMICAL CONDITIONS.

INTRODUCTION.

The area under consideration in this bulletin embraces practically the entire State of Nevada, the southern part of Oregon, the western part of Utah, and certain sections of eastern and southeastern California. It is confined on the north by the watershed of the Columbia, Snake, and Klamath Rivers, on the south and southeast by the Colorado River, on the west by the Sierra Nevada, on the east by the Wasatch Mountains, and on the southwest by the mountains bordering on the Mojave Desert. It includes the drainage of the Humboldt, Truckee, Carson, Walker, Quinn, Bear, Weber, Jordan, Salt, Sevier, Beaver, Amargosa, Mojave, and Owens Rivers and their tributaries, besides numerous smaller creeks and streams. It is considered as a unit because it has no surface drainage to the sea. Climatologically, it is a part of the arid region of the West.

The total area is estimated at between 208,500 and 210,000 square miles. The term "Great Basin" has received such widespread use and acceptance that we may consider the designation fixed, although it must not be considered as a single basin, but rather as a series of individual basins separated by mountain ranges. These basins are roughly of north-and-south trend. Five major systems may be separated and designated as the Bonneville; the Lahontan; the Amargosa and Death Valley; the Owens, Searles, and Panamint system; and the Oregon Lake system. Of the other lake basins not included in these systems the following may be named: Rhodes Marsh, Teels Marsh, Columbus and Fish Lake Valley, Clayton Valley, Alkali Lake (Paradise Valley, Cal.), Big Smoky Valley, White River, Mono, Saline Valley, Ivanpah, Bristol, Cadiz, and Danby. A complete list of the individual basins making up the Great Basin has been prepared by E. E. Free, and the following table is taken from his paper (The Present and Past Topography of the Undrained Areas of the United States):

Basin.	Description.	Area.	Basin.	Description.	Area.
		Square miles.			*Square miles.*
Lahontan		47,600	Humboldt-Carson	Part of Lahontan	27,575
Black Rock	Part of Lahontan	10,500	Fernley	do	215
Kumiva	do	445	Allan Springs	do	235
Granite Spring	do	890	Sand Springs	do	200
Jungo	do	340	Buena Vista	Part of Humboldt drainage.	4,000
Hot Springs	do	270			
Honey Lake	do	2,660	Buffalo Springs	do	500
Truckee	do	2,975	Gibson	do	1,150
Lemmon Valley	do	90	Clover (snow water)	do	1,075
Warm Springs	do	20	Walker	Part of Lahontan	3,850

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[1] This bulletin embodies the results of investigations carried on in cooperation with the United States Geological Survey and the Mackay School of Mines, Reno, Nev., with a view to determining the existence or nonexistence of sources of potash salts in the basin region.

Basin.	Description.	Area.
		Square miles.
Bonneville	Once tributary to Columbia River.	57,960
Steptoe	Part of Bonneville	6,590
Ruby	do	1,200
Butte Valley	do	740
Murray	do	720
White Valley	do	920
Rush Valley	do	700
Sevier	do	16,375
Christmas Lake	Probably landlocked	2,750
Silver Lake	Part of Christmas Lake Basin.	750
Chewaucan	Landlocked (Abert Lake).	1,500
Summer Lake	Part of Chewaucan Basin.	560
Alkali Lake	Landlocked	400
Warner	do	2,000
Harney	Tributary to Columbia River.	....
Catlow	Probably tributary to Harney.	2,000
Guano	Probably tributary to Catlow.	1,000
Surprise	Landlocked (maximum area).	2,350
Long Valley	Probably tributary to Surprise.	775
Duck Flat	Tributary to Surprise.	610
Alvord	Probably landlocked	3,200
White Horse	Tributary to Alvord.	300
Thousand Creek	do	1,300
Madeline	Probably landlocked	900
Goose Lake	Tributary to Pitt River.	....
Klamath Lakes	Tributary to Klamath River.	....
Dixie Valley	Landlocked	2,660
Fairview	Part of Dixie	285
Edward's Creek	do	400
Gabbs Valley	Landlocked	1,280
Acme	Probably tributary to Walker.	130
Luning	Probably tributary to Rhodes.	175
Mina	do	65
Rhodes	Probably landlocked (maximum area).	540
Garfield	Probably landlocked	90
Teels	Landlocked	320
Huntoon	do	115
Monte Cristo	Doubtful	300
Columbus	Landlocked (including Big Smoky).	5,225
Clayton	Landlocked	550
Big Smoky	Probably tributary to Columbus.	3,875
Smiths Creek	Probably tributary to Big Smoky.	550
Kingston	Tributary to Big Smoky.	1,190
Goldfield	Probably landlocked	330
Diamond Valley	do	930
Railroad Valley	Landlocked (maximum area).	6,340
Kawich	Probably tributary to Railroad.	370
Penoyer	Probably tributary to Railroad.	1,000
Gold Flat	Probably landlocked	640
Emigrant	Probably landlocked (maximum area).	1,000
Yucca	Probably tributary to Frenchman Flat.	300
Frenchman Flat	Probably landlocked	740
Indian Spring	Tributary to Colorado River.	650
Pint Water	do	730
Lee Canyon	do	300
Sheep Range	Probably landlocked	300
Spring Valley	Doubtful	1,550
Gannett	Tributary to Colorado River.	150
Opal Mountain	Probably landlocked	580
Mono	Landlocked	770
Aurora	Part of Mono	100
Owens	Once tributary to Searles.	2,825
Searles	Almost always landlocked (maximum area).	4,850
Panamint	Landlocked (area does not include Searles or Owens).	1,950
Saline Valley	Landlocked	825
Eureka Valley	Probably landlocked	550
Deep Springs	Landlocked	190
Kane	Probably landlocked	900
Willard	do	250
Granite Mountains	do	150
Owl	do	60
Death Valley	Landlocked (including Mojave and Amargosa).	23,160
Ralston	Part of Amargosa drainage.	1,750
Stonewall Flat	do	343
Sarcobatus Flat	do	755
Pahrump Valley	Tributary to Amargosa (maximum area).	1,400
Mesquite Valley	Probably tributary to the Amargosa.	350
Soda Lake	Part of Mojave drainage.	....
Rodriguez Lake	do	....
Harper Lake	do	....
Coyote Lake	do	....
Cronese Lake	do	....
Langford Lake	do	....
Ivanpah	Landlocked	....
Bristol Lake	Probably tributary to Colorado River.	....
Cadiz Lake	Tributary either to Danby Lake or to the Colorado River.	....
Danby Lake	Probably tributary to Colorado River (maximum area).	4,150
Mesquite Lake	Tributary to Colorado River.	....
Dale Lake	do	....

The areas given in this table are understood to be approximate. For a description of the basins given the reader is referred to the bulletin already cited.

Recent interest in the development of the potash resources of the United States has directed considerable attention to the possibilities of the Great Basin as a source of this compound. The Bureau of Soils and the United States Geological Survey have maintained investigators in this region for some time. Under the direction of the United States Geological Survey a bore has been sunk in the Carson Sink area to a depth of 985 feet. Many of the smaller basins have also been explored by shallow bores. Through the Bureau of Soils a study of the general conditions in these basins, and particularly dealing with the geochemical features, has been made. In order to widen out the field and stimulate prospectors and others to direct their attention to this mineral, the Bureau of Soils, the United States Geological Survey, and the Mackay School of Mines established a joint laboratory for the examination of mineral and other naturally occurring substances suspected to contain potash. The results of the United States Geological Survey investigators have been presented from time to time in bulletins.[1]

The results of the work of the Bureau of Soils are, in part, presented in a paper by E. E. Free (The Present and Past Topography of the Undrained Areas of the United States).[2] The purpose of the present paper is to present a review of the information now available on the subject of the occurrence and origin of the salines of the Great Basin region, as well as the chemical data which have been accumulated by the Bureau of Soils and the Cooperative Laboratory. Naturally a review of the geochemical features of a region of this extent will not be complete, but it is believed that such a review will be of value at this time and will indicate quite clearly the lines along which future investigation should be directed.

For an adequate conception of the geochemistry of a region it is necessary to know the principal facts concerning climatology, topography, geology, the surface and underground waters, the evaporation from ground and surface waters, and the distribution and chemical character of the rocks. These subjects will be treated in the order stated.

CLIMATOLOGY.

The Great Basin is spoken of as an arid region, and just what is the significance of this term may be gathered from the tables in the Appendix. These tables have been compiled from Weather Bureau reports on precipitation and temperature. They are grouped in four divisions: Weather stations in Nevada, weather stations in western Utah, weather stations in the part of the basin region included in Oregon, and weather stations in that part of the basin region included in California. The altitude and mean annual rainfall of each station is given. (See Appendix, Table I.) The average (arithmetical mean) annual rainfall of the stations in each group is, for the Oregon group, 13.59 inches; for the Utah group, 12.8 inches; for the Nevada group, 10.34 inches; and for the California group, 4.43 inches. The mean annual precipitation for the entire basin region is 10.31 inches. In arriving at this average the mean for each of the above groups and the area occupied by each group were taken into consideration. The variation of the mean annual rainfall with latitude in the basin region may be approximated from Table II. (See Appendix.) Latitude is less a factor in controlling precipitation than altitude. The basins of the Great Basin in general are characterized by a small rainfall. The higher mountains receive a much greater rainfall. An area of high aridity may be marked out, and this includes the Mojave Desert, the Amargosa Basin, the Owens, Walker, Mono, Pyramid, Carson, and Black Rock Desert regions. In this area the mean annual precipitation is less than 6 inches.

An inspection of the weather reports for the basin region shows that some precipitation takes place in each month of the year. December, January, February, and March are the usual months of maximum precipitation; while June, July, August, and September are the months of minimum precipitation. There is, however, much irregularity in the monthly distribution of the rainfall, and the weather charts do not give an entirely clear conception of the situation. Rainfall may be divided into two classes—the normal winter precipitation and the precipitation which usually occurs in August and September. The latter is in the nature of torrential rains and cloudbursts and is conspicuous in the more arid portions of the region. The normal winter precipitation contributes but little run-off in the arid portions, but the August and September precipitations often result in heavy local run-offs which are important agents in the movement of detrital material from the mountains to the plains. As might be expected, precipitation of this nature is very irregular. Several years may elapse without sufficient rain to even moisten the desert watercourses. Then a period of heavy rains results in turning such watercourses into torrents. Stream flows of this nature are of short duration, but the local work of erosion and transportation may be very great. Were it not for these rains, erosion and deposition in the more arid portions of the basin region would be somewhat inconspicuous and limited principally to the action of wind. The influence of these torrential rains extends over the whole arid region described above. But little study has been made of these storms, their distribution, and frequency of occurrence. As might be inferred, the weather reports would not reflect this phase of the precipitation to any marked extent.

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[1] Bul. No. 523, Nitrate Deposits. Bul. No. 530–A, The Search for Potash in the United States; Potash Salts—Summary for 1911. Bul. No. 511, Potash Salts—Their Uses and Occurrence in the United States; Alunite. Bul. No. 530–R, Exploration of Salines in Silver Peak Marsh, Nevada; Press Notice No. 97, Feb. 10, 1913; Prospecting for Potash in Death Valley.

[2] Circ. No. 61, Bureau of Soils, An Investigation of the Otero Basin, New Mexico, for Potash Salts; Circ. No. 62, Bureau of Soils, Report of a Reconnoissance of the Lyon Nitrate Deposit near Queen, New Mexico.

The mean annual temperature and the highest and lowest temperatures are given in Table III (See Appendix). It is worthy of note that the temperature range in the basin region is great. Extreme cold often prevails in the northern part and extends well down to the south. Extreme summer heats are characteristic of the southern portions and extend well up to the north. As a consequence of this, rock disintegration would be a not inconspicuous feature of the higher mountains.

TOPOGRAPHY.

The dominant bounding ranges of the basin region are the Sierra Nevadas on the west and the Wasatch on the east. The area between these ranges may be considered as a plain intersected by mountain ranges of a predominantly north and south trend. The plain, which is really a great system of more or less connected intermountain valleys, maintains its elevation of between 4,000 and 5,000 feet altitude over practically the entire northern half of the region. The northern half contains three of the main drainage basins—the Bonneville, the Lahontan, and the Oregon Lake basins. These basins are all close to or within the 4,000-foot contour. The south-central half of the plain slopes gradually to the south, reaching two points of maximum depression—Death Valley on the southwest and Las Vegas Valley on the southeast. If we consider the Salton Lake area as a portion of the Great Basin, we have another point of low depression in the Salton Sink. The principal river within the basin is the Humboldt. This river flows across Nevada and feeds Humboldt Lake, in the Lahontan basin. Of minor importance are the Quinn, Amargosa, Reese, and White Rivers. From the Sierras and the Wasatch Mountains many important streams feed the lakes lying in the Bonneville and Lahontan basins and along the base of the Sierras. Many minor streams flow from the short, steep canyons of the higher mountain ranges of the basin.

The mountains of the basin region are in many instances characterized by steep scarps on either or both sides. Short, steep canyons cut to the summits are the rule. Only in a few instances are gently rising slopes to the higher summits to be found. The topography of the mountains belongs to an intermediate rather than a mature or juvenile type.

The valleys are wide and often of great north and south extent. Fringing the valleys are alluvial fans or cones. They are less noticeable in the north, but become conspicuous in the south, where they reach enormous proportions in the Death Valley region.

An attempt has been made to determine the proportion of mountain and intermountain area. The Sierra Valley, Reno, Wadsworth, and Carson topographical sheets were measured and the areas occupied by mountain, outwash slope, silt, playa, and lake determined by planimeter measurements. A more or less arbitrary division was made between mountain and outwash areas, and between outwash and silt areas. Outwash areas include the alluvial fans or cones fringing the steep slopes of the mountains. Where the contours indicated a 2° to 4° slope, the beginning of the silt area was assumed, while the blue dotted line upon the topographic sheets surrounding the lowest area of an intermountain space was taken as the playa area. Similar measurements were made upon the topographic sheets of the Amargosa River. The results of these measurements, as well as those made in the Owens River Valley, are given in Table IV (Appendix). Figure 1 graphically illustrates the comparison of the areas measured, with the exception of the Owens Valley area. The measurements given may be taken to represent a close approximation to the conditions within the basin region. The mean of the measurements of the Carson and the Amargosa region is: Mountain area, 48.3; outwash slopes, 19.1; silt area, 26.8; playa and water area, 5.5 per cent. The mean may be taken to represent approximately the basin region. The figures may be interpreted to mean that over approximately one-half of the basin region erosion is active, while on the remaining half deposition is taking place, greatest in amount on the outwash slopes and least in the playa and flat portions of the intermountain areas. The material constituting the outwash slopes is, in the main, coarse and angular. It is itself more or less subject to erosion. The fine silt and sand coming from the mountain areas, as well as the eroded material of the outwash slopes, finds its way into the playa areas.

GEOLOGY.

An extensive review of the geology of the basin region would be out of place here. Briefly, all of the geological divisions, with the exception of the pre-Cambrian, Permian, and Cretaceous, are to be found. For our purpose we may consider these geological time divisions in three groups—pre-Tertiary, Tertiary, and post-Tertiary.

Pre-Tertiary rocks embrace a comparatively large area of the basin region. The chief formations are: Cambrian, Silurian, Devonian, Carboniferous, Triassic, and Jurassic. Pre-Cambrian formations have been described by King, Spurr, and Ball, but are relatively unimportant. The eastern and southeastern part of Nevada is characterized by Cambrian, Silurian, Devonian, and Carboniferous rocks. These rocks are quartzites, slates, limestones, and sandstones. Triassic and Jurassic formations are relatively less abundant and occur in widely distributed patches in the west-central and southwest portions of the basin region. They consist of limestones, slates, shales, and thin beds of quartzite. In the Triassic are also found beds of gypsum.

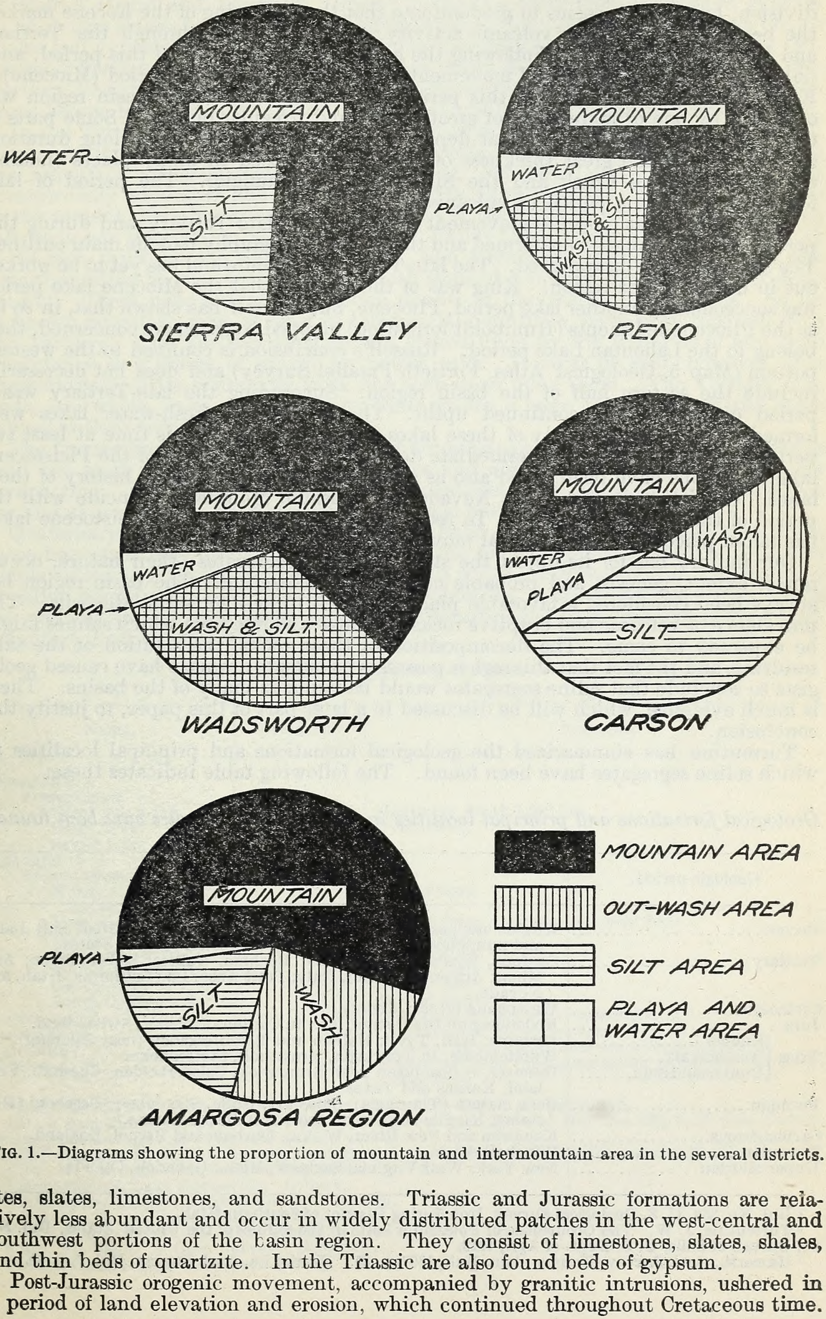

FIG. 1.—Diagrams showing the proportion of mountain and intermountain area in the several districts.

Post-Jurassic orogenic movement, accompanied by granitic intrusions, ushered in a period of land elevation and erosion, which continued throughout Cretaceous time.

The conspicuous absence of Cretaceous formations in the basin region, excepting in the Wasatch Mountains and the Iron Spring district of southern Utah,[1] has been noted by many geologists and confirms the conclusion that the basin region was a land mass in Cretaceous time.

The pre-Tertiary was ended and the Tertiary begun by orogenic movement, accompanied by volcanic eruptions. Evidence is not conclusive as to the exact geologic division, but opinion seems to predominate that the beginning of the Eocene marked the beginning of Tertiary volcanic activity, which extended through the Tertiary and into the Quaternary. Following the early volcanic activity of this period, and, no doubt, preceded by crustal movements, was the Tertiary lake period (Miocene)—King's Pahute Lake. During this period the western half of the basin region was occupied by one or more lakes of great extent and irregular outline. Some parts of this lake were, no doubt, of great depth, and the lake period was of long duration, as is shown by the great thickness of sediments exposed in many places (notable examples: Furnace Creek and the Silver Peak quadrangle). The period of lake formation was also a period of vulcanism.

A period of great orogenic movement succeeded the late Tertiary, and during this period the basin ranges were formed and the present topography took its main outlines. The Miocene lakes disappeared. The late-Tertiary is obscure and has yet to be worked out in detail for the region. King was of the opinion that the Miocene lake period was succeeded by another lake period, Pliocene, but Russell has shown that, in so far as the Pliocene sediments (Humboldt formation) mapped by King are concerned, they belong to the Lahontan Lake period. Russell's conclusion is confined to the western portion (Map 5, Geological Atlas, Fortieth Parallel Survey) and does not necessarily include the eastern half of the basin region. Succeeding the late-Tertiary was a period of erosion and continued uplift. The Pleistocene fresh-water lakes were formed. The detailed study of these lakes has shown during this time at least two periods of flooding and an intermediate desiccation. Fluctuations of the Pleistocene lake elevations have been noted also as a conspicuous feature in the history of these lakes. Glaciation in the Sierra Nevada and Wasatch Mountains coincide with the period of the Pleistocene lakes. In recent time desiccation of the Pleistocene lakes has taken place and minor crustal movements have continued.

Our inquiry has for its object the study of saline segregates—their nature, occurrence, extent, genesis, and probable commercial utilization. The basin region has always been considered a favorable place in which to look for saline deposits. The prevalence of volcanic and eruptive rocks indicates a source from which salines might be expected to come. The decomposition of these rocks, the solution of the salts resulting, and the fact that this region possesses no outside drainage have caused geologists to conclude that saline segregates would be found in many of the basins. There is much evidence, which will be discussed in a later part of this paper, to justify this conclusion.

Turrentine has summarized the geological formations and principal localities in which saline segregates have been found. The following table indicates these:

Geological formations and principal localities in which saline segregates have been found.[2]

Geologic period.	Locality.
Recent	Kirghiz steppes; Arabia; South America; Dead Sea; Great Salt Lake, and numerous other ancient lakes in western United States.
Tertiary	Cardona, Spain; Wieliczka and Bochnia, Galicia; Siebenbürgen; Asia Minor; Armenia; Rimini, Italy; Petit Anse, La.; California, Utah, and Nevada.
Cretaceous	Westphalia brines; Algiers.
Jura	Rodenberg on the Deister; Bex in Canton of Waadt, Switzerland.
Trias Keuper	Lorraine; Hall, Tyrol; Hallein and Berchtesgaden (near Salzburg).
Trias Muschelkalk	Wurttemberg; in Thuringia, Ernsthall, Stottenheim.
Trias Buntersandstein	Hanover, Schoeningen near Brunswick, Salzderhelden; Cheshire, England; Kansas and Texas.
Permian	Gera, Artern (Thuringia); Staasfurt, Halle, Sperenberg; Segeberg (Holstein); Kirghiz steppes on the River Ileck; Kansas.[3]
Carboniferous	Kanawha and New River, W. Va.; Durham and Bristol, England.
Devonian	Winchell, Mich.
Upper Silurian	New York; West Virginia; Saginaw, Mich.; Goderich, Canada.

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[1] Bul. No. 338, U. S. Geological Survey, Iron Spring District of Southern Utah.

[2] Turrentine, J. W. The Occurrence of Potassium Salts in the Salines of the United States, Bul. No. 94, Bureau of Soils, U. S. Dept. of Agr., 1913.

[3] Haworth, Geol. Survey, Kansas; Ann. Bul., 1897, p. 56. Harris, La. Geol. Survey, Bul. 7, p. 94.

In pre-Tertiary formations salines have been reported from the upper Silurian, Devonian, Carboniferous, Permian, Triassic, Jurassic, and Cretaceous. These formations, excepting Permian and Cretaceous, are represented to a greater or less extent in the Great Basin. In spite of extensive search on the part of geologists and prospectors, no beds of salines of commercial importance other than gypsum have been discovered. Louderback[1] notes the occurrence of gypsum beds in the Triassic at Mound House and Lovelock. Spurr[2] notes the occurrence of massive gypsum in lenticular masses in the upper Carboniferous at Cottonwood Springs. Rowe[3] notes shales and gypsum beds overlying the upper Carboniferous in the hills north of Cottonwood Springs. A review of the literature leads one to conclude that in the pre-Tertiary formations, excepting the gypsum deposits and minor occurrences of saliniferous layers, the prospects of finding salines of commercial importance are not good.

In the Tertiary formations of the basin region saline segregates have been found. The most important occur in Miocene lake beds. Borates, gypsum, and salt are the important minerals that have been noted. Of these, the borates have been commercially exploited and produce the borax supply of the United States. Up to the present there has been little utilization of the gypsum beds. Concerning the salt beds our information is scanty. G. E. Bailey[4] describes a bed of rock salt 12 to 16 feet thick in the Saratoga district, San Bernardino County, Cal. He also describes saline beds occurring on the north slope of Avawatz Mountains in the same county. These beds are, without much doubt, in the Tertiary lake series. So far as known no potash salts, at least in commercial quantities, have been reported from the Tertiary. The Tertiary beds are not looked upon by the writer as of any great importance as a source of supply for potash salts. It must be said, however, that comparatively little systematic work has been done upon them. The Tertiary lake beds, as a whole, have contributed by their erosion a large amount of salt and other salines to their tributary basins.

The Quaternary lake beds and the lakes accompanying the Quaternary lake basins hold the most important supplies of salines and are the most promising fields for prospecting. Pre-Tertiary and Tertiary formations have supplied the salts which we find as accumulations in the recent drainage basins and lakes.

Quaternary and recent geologic history has been studied in detail in several of the more important lake basins, and we have in the monographs of Russell and Gilbert ample information of the changes in conditions which have resulted in the formation of saline deposits in these basins. The complete list of the Quaternary lake basins has perhaps not yet been made. From the literature and from personal notes I have compiled the following table:

List of Quaternary lakes.

Name.	Elevation.	Remarks.
Bonneville:[5]		
Present lakes—	*Feet.*	
Great Salt Lake	4,200	Maximum depth 1,050 feet.
Utah Lake		Overflowed.
Sevier Lake		
Lahontan:[6]		
Present lakes	4,405 to 4,414	
Honey and Eagle Lakes.	3,949	326 feet deep.
Pyramid Lake	3,880	886 feet deep; 525 feet above 1882 level.
Walker Lake	4,083	435 feet deep.
Winnemucca Lake	3,875	530 feet deep.
Humboldt Lake	3,929	500 feet deep.
Carson Sink	3,900	526 feet deep.
South Carson Lake	3,916	510 feet deep.
Owens Lake[7]	3,569	Old beach 190 feet above present level.
Searles[8]	1,700	Shore line 600 feet above flat.
Panamint[9]	1,046	1,000 feet above valley floor are wave-cut terraces.
Mono[10]	6,426	Quaternary area 316 square miles; beach 670 feet above lake level.

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[1] Bul. No. 223, U. S. Geol. Survey, Gypsum Beds of the United States, p. 118.

[2] U. S. Geological Surveys West of 100th Meridian, vol. 3, p. 166; and Bul. No. 208, U. S. Geol. Survey, Geology of Nevada south of fortieth parallel survey.

[3] Bul. No. 208, U. S. Geol. Survey, Geology of Nevada south of the fortieth parallel, p. 170.

[4] Bul. No. 24, California State Mining Bureau, p. 126.

[5] Monograph I, Lake Bonneville. Gilbert.

[6] 11th Annual Report, Lake Lahontan. Russell.

[7] Bul. No. 24, Cal. State Mining Bureau.

[8] 10th Annual Report, Cal. State Mineralogist.

[9] Bul. No. 200, U. S. Geol. Survey. Campbell.

[10] 8th Annual Report, U. S. Geol. Survey.

List of Quaternary lakes—Continued.

Name.	Elevation.	Remarks.
	Feet.	
Columbus [1]	4,559	Shallow lake 50 to 60 feet deep.
Railroad Valley [2]	4,700	Highest shore line 300 feet above flat.
Dixie [2]	3,500	Highest beach line 150 feet above floor.
Surprise Valley: [3]		
Upper, lower, and middle alkali lakes.	5,190	Highest beach line 550 feet above present level. Two high-water lines.
Lake Alvord [4]	4,200	Highest beach line 100 feet. Four well-marked and 2 faint lines.
Catlow Valley [4]	4,600	Highest beach 75 feet. Three well-marked beach lines.
Warner Lake [3]	4,600	Highest beach line 225 feet.
Abert Lake: [3]		
Chewaucan Marsh	4,400	Beach line 260 feet above Chewaucan Marsh.
Summer Lake	4,300	Beach line 300 feet above Summer Lake.
Jumper Lake	4,400	Two shore lines 30 and 60 feet above present lake.
Long Valley	5,945	Shore line 250 feet above present level.
Silver Lake	4,340	Beach line 100 feet above present level.
Christmas Lake		
Madeline Plains	5,400	Overflowed.

Ruby and Franklin Lakes, Nev.; Danby and Bristol Lakes, Cal.; and Diamond Valley, Nev., doubtful.
Tahoe Lake reported by Diller to show old shore lines above the present lake level.

[1] H. S. Gale (?)

[2] E. E. Free.

[3] 4th Annual Report, U. S. Geol. Survey. Russell.

[4] Water Supply Paper 231.

Ratios of basin area to lake area, and of Quaternary lake area to present lake area.

Lake.	Basin area.	Quaternary lake area.	Ratio of basin area to Quaternary lake area.	Present lake area.	Ratio of Quaternary area to present area.
Bonneville	52,000	19,750	2.63	2,498	7.9
Lahontan	47,600	8,422	5.65	734.6	11.4
Total	99,600	28,172	3.53	3,232.6	8.71

Total present area of all the lakes in the Great Basin, 4,196 square miles.
Total area of all the Quaternary lakes, estimated, 36,547 square miles.
Ratio of total area of Great Basin to total Quaternary lake area, $\frac{210000}{36547}=5.74$; to total present lake area, $\frac{210000}{4196}=50$.

The present lakes, occupying in many instances the lowest depressions in the Quaternary lake basins, are given in the next section. The chemical data concerning both the Quaternary and the recent lakes and their basins will be given in another section of this report.

SURFACE WATERS.

Complete data are not available for the determination of the total run-off in the basin region. From the Water Supply Papers of the United States Geological Survey it is possible to secure data for the principal streams, but many small streams of local importance are to be found in the mountains of the Great Basin, and for these we have practically no data. These streams contribute to the underground-water supply, but seldom do their waters reach the surface of the playas except in periods of unusual rainfall. The ponds and shallow lakes resulting are quickly evaporated.

The principal streams are: In western Utah, the Weber, Bear, Logan, Spanish Fork, Sevier, and Provo; in Nevada, the Humboldt, Truckee, Carson, Walker, Reese, Quinn, and Amargosa; in California, Susan River, Owens River and tributaries, Leevining Creek, Mill Creek, and Mojave River; in Oregon, small creeks and streams which contribute to the lakes in southern Oregon. Such data as are available for the above streams are given in Tables V, VI, VII (Appendix).

Basin river streams may be divided into three types:

(1) Streams characteristic of the higher mountains. These are short streams which take care of the winter precipitation and carry their waters to the outwash slopes to be distributed by the porous detrital fans.

(2) Streams, such as the Amargosa, Reese, and Quinn Rivers, which reach main basins but do not carry sufficient water to make a continuous flow, or which reach basins of such magnitude that they can not form permanent lakes.

(3) Streams which supply permanent lakes. The drainage of the Sierra Nevada and Wasatch Mountains supplies practically all of these lakes. Owens, Mono, Carson, Walker, Pyramid, Honey, and the lakes of southern Oregon are typical examples of such lakes in the west; while Great Salt Lake, Utah Lake, and Sevier Lake are in the east and are supplied by the drainage of the Wasatch Mountains.

A list of these lakes, together with elevations and drainage area of basins, is given in Table VIII (Appendix).

The proportion of the annual precipitation which appears as run-off varies in different basins. The length of the stream and the character of the watershed, as well as local climatic conditions, determine this factor. The following table summarizes the run-off factor for the Carson, Walker, Truckee, and Humboldt Rivers.

Proportion of rainfall distributed in the run-off.

River basin.	Average rainfall, mean annual.	Run-off.	Run-off in percentage of average rainfall.
	Inches.	*Inches.*	
Carson	11.5	6.25	54.3
East Fork Walker	11.5	2.63	22.8
Truckee	23.82	9.18	38.9
Humboldt	8.12	0.25	3.07
Whole basin region	10.31	[1] 0.71 [2] 1.19	[1] 6.80 [2] 11.50

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[1] By calculation based upon the total mean annual stream flow, plus an additional amount estimated at one-half the known amount for the flow of the streams upon which no data are available.

[2] By calculation based on an assumed rate of evaporation of the water from the lakes into which the rivers flow.

In addition, an attempt has been made to calculate the probable total run-off for the whole basin region. The first calculation is based upon the total mean annual stream flow plus an arbitrary amount for the flow of the streams upon which no data are available. The additional amount has been estimated as one-half of the known amount. This gives a run-off equivalent to 0.71 inch, or 6.8 per cent of the total precipitation. The second calculation is based on an assumed rate of evaporation of the water from the lakes. The total area of lake surface is 4,196 square miles. Assuming an annual evaporation of 60 inches gives an annual run-off of 1.19 inches, or 11.5 per cent of the average annual precipitation. The latter figure is undoubtedly high, as in the southern half of the Great Basin the run-off is practically zero. For instance, the Amargosa River is a typical desert stream and flows only at rare intervals and during periods of excessive precipitation. At other times water occasionally rises in springs from the dry bed, flows a short distance, and then sinks. The run-off for this whole southern area must be less than 1 per cent.

As more than 50 per cent of the area of the Great Basin is flat, or characterized by slopes of low angles (0 to 5°), it may be assumed that for areas of this nature, receiving 10 inches or less mean annual rainfall, the run-off is practically zero. For the basin ranges themselves the run-off can not be in excess of 50 per cent, and it is probably much less. Much of this run-off is absorbed by the outwash slopes. We may take the Humboldt River as an example to illustrate this point. This stream rises in the Ruby Range, upon which there is considerable precipitation. At Oreana the mean annual flow gives a run-off of 0.25 inch (drainage area, 13,800 square miles), or 3.07 per cent of a mean annual rainfall of 8.12 inches. This means that most of the rainfall in the mountains along the course of the Humboldt is absorbed before it can reach the main river.

The basin region may be divided into mountain area, outwash area, and combined silt and playa areas. These approximate 50, 20, and 30 per cent, respectively, of the total area. An inspection of the precipitation tables given on a preceding page shows that the lowest part of a basin often receives less than 5 inches of annual rainfall and the surrounding mountains a much larger amount. The disposal of the rainfall is illustrated in the following summary:

Distribution of rainfall.

Region.	Percentage of whole area.	Mean annual precipitation.	Percentage.		
			Evaporation.	Seepage.	Run-off.
		Inches.			
Mountain area	50	13	50	10	40
Outwash area	20	10	50	40	10
Silt and playa area	30	5	100	....	....

Of the run-off from the mountain area given in the above table probably more than one-half is lost by seepage in the outwash area. This would leave only 20 per cent of the mountain rainfall as run-off, and of the 10 per cent run-off of the outwash area we might well say that all is lost by seepage. Twenty per cent of 13 inches is 2.6 inches. This comes from one-half of the entire area and would be equivalent to 1.3 inches over the whole area. A large part of the seepage water is brought to the surface by capillarity and lost by evaporation. It is admitted that the proportions estimated for evaporation and seepage in the above table are more or less arbitrary. Still, we may qualify some of these figures by comparison. The run-off factors for streams in the Sierra Nevada Mountains vary considerably. The average for the Kings, Merced, Tuolumne, Tule, Kern, Carson, Walker, and Truckee is 42.7 per cent. This would justify the 50 per cent run-off figure estimated. For the outwash slopes a percolation figure of 80 per cent is not unreasonable and for the silt areas 100 per cent.

From three lines of inquiry are obtained 0.71, 1.19, and 1.30 inches as the run-off for the basin region. The mean of these is 1.06 inches, or 10.3 per cent of the mean annual precipitation of the Great Basin.

It should be noted, however, that the southern portion of the basin region is characterized by a scanty and irregular run-off, only a fraction of that indicated above, while the run-off for the area contiguous to the Sierra Nevada and Wasatch Mountains is, no doubt, much higher than the above.

EVAPORATION.

Practically all of the rainfall of the basin region is lost by evaporation. During periods of excessive precipitation there is undoubtedly an increase and during periods of aridity a decrease in the amount of ground water. Evaporation from the surface of lakes, from the surface of the ground, and the transpiration of plants are the three ways by which the water is taken back into the atmosphere. How important each of these factors is in the basin region is the subject of our inquiry.

Many experiments to determine the amount of evaporation from surface waters have been made and variable results have been obtained. Some of these results, such as more particularly apply to this region, are given in the following table:

Evaporation from water surfaces.

Locality.	Conditions.	Annual evaporation.
		Inches.
Owens Valley region, Cal.[1]	Evaporation from pan in water, 1909 and 1910	69.05 65.44
Owens Valley region, Cal., Owens Lake.	Deep tank in soil, 1910	69.01 80.00
Bishop	Pan in irrigation ditch	60.00
Fallon, Nev.[2]	4-inch pan floating in canal	53.65
Lake Tahoe, Cal	4-inch pan 2 inches above water	42.21
Salton Sea, Cal	4-inch pan 7,500 feet from sea	106.45
Pyramid Lake, Nev.[3]	Estimated from mean flow of Truckee	60.00
Great Salt Lake[4]	....	90.00

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[1] Bul. No. 294, Water-Supply Papers.

[2] American Civil Engineering Pocket Book.

[3] Bul. No. 52, Nevada Exp. Sta.

[4] U. S. Geol. Survey Report No. 11.

Evaporation from water surfaces varies with the seasons. It is greatest in the summer and fall months. In the Owens River region 73 per cent of the annual evaporation takes place in the six summer and fall months, and the remaining 27 per cent in the winter and spring months. We have not sufficient data to strike an average for the whole basin region, but it is believed that an annual evaporation of 60 inches would fairly represent that which takes place from the surface of the lakes in the basin region.

From an intensive study made of conditions in the Owens River basin [1] the following figures for the evaporation of water from ground surfaces are taken. The annual ground-surface evaporation depends largely upon the depth of ground water. Where the ground water exceeds 10 feet in depth practically no water is lost from the surface. Where ground water and ground surface coincide the maximum of 42.3 inches per year is found; with ground water at a depth of 1.34 feet from the surface 39.95 inches is found; and with ground water 4.98 feet below the surface 7.9 inches is found. Of the annual evaporation the summer and fall months account for 79 per cent of the total.

Observations in the same locality established the fact that even in a wet season percolating water does not penetrate to depths exceeding 2½ feet unless more than 1 inch falls within a short period on moist soil. Even then it does not appear to reach depths greater than 4 feet. We would conclude from these observations that on detrital fills, on levels, or on low slopes, much of the rainfall is retained close to the surface and seldom penetrates to depths reaching 10 feet. It can not, therefore, form any permanent addition to the ground water, but must be lost by capillarity and evaporation. On steeper slopes the water penetrates slowly downward and in the lower portions of such slopes may be expected to accumulate sufficiently to reach the 10-foot level, and thus a part escapes loss by joining the permanent ground water. Streams debouching upon outwash slopes raise a ridge in the ground-water level and contribute a part of their seepage loss to permanent ground water. We would also conclude that ground water 10 feet or more from the surface would be permanent, and that ground water reaching the 10-foot level or less would be reduced in amount by evaporation. It should be noted that this limit of 10 feet can not be applied to all conditions, for in very fine silts capillarity would no doubt extend to a greater depth than 10 feet. It does, however, establish a limit under what we might term average conditions within which capillarity becomes effective. We would expect in all regions of the basin where ground water reached within the 10-foot level that a slow upward movement of moisture would follow. In this manner soluble salts would be brought to the surface or close to it and would appear as incrustations or be deposited within the surface soil. We should be safe in concluding that where surface incrustations are found in quantity ground-water levels are apt to be within the 10-foot limit. This is, of course, not an entirely accurate criterion, for surface waters may penetrate to depths of several feet and be returned by capillarity, carrying with them dissolved salts to the surface, where they would crystallize and form efflorescences.

Still another fact should not escape our attention. If we assume a soil void space of 25 per cent of volume, a depth of 30 inches of water would be necessary in order to saturate the soil to a depth of 10 feet. In a loose coarse soil but a small fraction of these 30 inches would be required for water to penetrate and reach to a depth of 10 feet. In a mixed soil with much fine silt and clay probably a large proportion of this would be retained, if it penetrated at all, in the upper 10 feet. The low average rainfall of the desert region, together with the observed facts concerning the penetrations of soil by rainfall in the Owens region and the fact noted above, would lead us to conclude that were it not for the concentration of part of the rainfall into stream flows the ground water of the basin region would be a negligible quantity and would be present only in those places where subterranean supplies could act as feeders or in places occupying the lowest depressions of the surface. While these conclusions may be accurate for present climatic conditions it must be kept in mind that the basin region has been subjected to many climatic changes. Humid periods have alternated with arid. We may be not greatly in error when we say that the underground water supply of the basin region is perhaps consequent upon the greater rainfall of the Quaternary period and not upon present climatic conditions.

The surface of the Great Basin is covered with sparse vegetation. One is apt to get the idea from reading maps that vegetation is extremely scarce in the basin region, but we find some kind of vegetation over the whole area, with the exception of the playas and areas occupied by alkali incrustations. Many of the mountain ranges of the basin are thickly covered with grass, and sagebrush dominates over vast areas of plain and mountain slope. We have no accurate determinations of the transpiration loss of desert plants. Such work as has been done on this question has concerned itself usually with farm crops. On the whole this question has no very important bearing upon our problem and may consequently be dropped.

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[1] Water-Supply Paper No. 294.

In the section on surface waters it is shown that approximately 10 per cent of the mean annual rainfall occurs as run-off in the basin region. The evaporation from lakes, rivers, and transient ponds would be measured by this run-off. The remaining 90 per cent of the mean annual precipitation would be a measure of the evaporation from the surface of the ground, by transpiration of plants, and additions by seepage to permamanent ground water. It is believed that the addition to permanent ground water is relatively small.

GROUND WATER.

A comprehensive study of ground-water conditions in the Great Basin has yet to be made. Some important information pertinent to our subject is available. I have summarized the data under the following heads: Ground water in valleys and sinks; in outwash slopes; deep supplies of water; artesian water; springs; and fissure and rock water.

VALLEYS AND SINKS.

Ground water is encountered in the Lovelock Valley at depths of 15 to 25 feet.[1] In this valley, after a considerable period of irrigation, ground water has been found at depths of 3 to 6 feet. The figures given in the first statement would represent original conditions, before irrigation took place. This valley is a silt-filled valley on the lower stretches of the Humboldt River.

In the Truckee meadows ground water is found at 10 to 12 feet from the surface in the vicinity of Reno, and on the eastern edge of the Truckee Meadows it stands practically at the surface. In south-central Oregon and the Harney Basin much detailed information is available. In Christmas and Silver Lake Valleys 46 wells and bores have been reported.[2] Most of these wells are located in the valley and lake silts. The depth to ground water varies from 5 to 49 feet. The average depth of water in all the wells reported is 18 feet. In the Harney Basin 46 wells have been reported.[3] The average depth of water in these wells is 21 feet.

In the Owens River Valley, Cal., a survey of underground waters was made by the United States Geological Survey,[4] and these were found to stand at 2 to 3 feet below the surface over considerable areas. Over the comparatively level valley floor west of Owens River and included within the 8-foot contour above the river (67 square miles of surface) "the average depth to ground water between 4 and 8 feet extended over 40 per cent of this area, and between 3 and 4 feet over 28 per cent. It extends 8 feet in depth over 14 per cent of the area and is 3 feet or less over 18 per cent."

In the Silver Peak Marsh borings showed ground water at 2 to 12 feet depth and, in the case of many of the bores, water was encountered at 4 feet.[5] In the sink in Death Valley water is found a few inches below the salt crust and potholes in the rough salt areas indicate that ground water stands within 1 or 2 feet of the surface over a considerable area. On Searles Marsh Dolbear[6] reports the brine (over the salt area) to be within one-half inch of the surface.

At Millers, Nev., wells have been sunk in the desert sands of Big Smoky Valley and water sufficient to supply 160 stamps has been tapped at a depth of 65 feet. The ground water in Big Smoky Valley undoubtedly comes much closer to the surface in the playa southwest of Millers.

Mina is situated in the valley which forms the south extension of the basin occupied by Walker Lake. It is a typical desert valley. Two wells struck water at 112 and 118 feet from the surface.

Other examples could be cited, but these are sufficient to show that in the playa areas and the low areas generally we may expect to find ground water at no inconsiderable depth from the surface. The area within which the ground water would collect would depend upon the extent of the tributary basin and the rainfall within the basin.

OUTWASH SLOPES.

The ground-water conditions in the outwash slopes may best be illustrated by the following quotation[7] describing the conditions in the Owens River Valley:

"The ground-water surface as it approaches the valley floor from the west has an average slope of 90 feet to the mile. The corresponding slope of the ground surface is steeper, varying from 150 to 110 feet to the mile. At the upper edge of the grassland the two surfaces are about 8 feet apart and a short distance beneath they intersect in the spring belt. From this belt to Owens River the distance to ground water varies from 4 to 12 feet beneath the gently sloping or level valley floor. This sudden break in the slope of the ground-water surface at the spring belt is caused by the change from coarse to fine material in the region of the late lake. The fine material acts somewhat like a dam, raising a portion of the ground water to the surface in springs and retarding the lateral movement of the remainder."

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[1] Bul. No. 52, Agr. Expt. Sta., University of Nevada.
[2] Water-Supply Paper No. 220, U. S. Geol. Survey.
[3] Water-Supply Paper No. 231, U. S. Geol. Survey.
[4] Water-Supply Paper No. 294, U. S. Geol. Survey.
[5] Bul. No. 530R, U. S. Geol. Survey, pp. 7–11.
[6] Engineering and Mining Journal, Feb. 1, 1913, p. 260.
[7] Water-Supply Paper No. 294, p. 76.

The above quotation indicates a condition which must be common in basins characterized by surrounding alluvial cones. The ground-water level assumes a sloping surface, and, as we ascend the cone from the valley, we find this ground-water surface at greater and greater depths. We would expect that in every case at the toe of the alluvial fan the ground-water level would be closest to the surface and deepest in the vicinity of the bordering mountains. The amount of seepage water that would collect from the contiguous watersheds, together with the rainfall, would determine whether the upper surface of this ground water would be close to or at considerable depth from the surface.

DEEP SUPPLIES OF WATER AND ARTESIAN WATER.

The bore hole put down by the United States Geological Survey in the Carson Sink region encountered surface waters at a depth of 4 feet, and at depths greater than 150 feet a number of artesian flows were encountered. The well which was put down some 985 feet flowed water.

The Railroad Valley Saline Co. sunk a 1,200-foot bore in Railroad Valley. They discovered many flows of artesian water from the 128-foot depth downward. Twenty-nine separate flows are noted in the log of their well within the first thousand feet. At greater depth the formations were dry.

Artesian areas are known in Smith Valley, Nev.; the Truckee Meadows south of Reno; the Carson Valley, Nev.; the Las Vegas Valley, Nev.; the Salt Lake Valley, Utah; and in southern Oregon. These instances lead us to conclude that water-bearing strata exist in many of the inclosed basins and at depth, and in many cases that they are capable of supplying artesian water.

SPRINGS.

Many springs exist in the Great Basin region. A complete list of these springs can not be given at this time. Russell, in his study of the Quaternary lakes of western Nevada, mapped the springs occurring in this area. He shows 93 springs in an area of approximately 38,000 square miles. Of these 23 are hot springs. Outside of this area hot springs are encountered in many places. South of Beowawe some 6 miles are a number of hot springs and geysers. Just west of Elko is a large hot spring. Sixty miles north of Elko is an area in which several hot springs of considerable size occur. At Rhyolite, Nev., several small hot springs are to be found. Some 12 miles northwest of Goldfield is a hot spring of moderate size. In Railroad Valley a large hot spring has been found. The prevalence of hot springs in the basin region may be assumed to indicate the presence of deep-seated waters. Hydrothermal activity has long been noted as an important feature of the basin region. In earlier geological periods undoubtedly much greater activity existed than at the present.

FISSURE AND ROCK WATER.

That much water may be expected in fissure and brecciated zones in the mountain ranges is shown by the volumes of water encountered in mining operations. Virginia City is perhaps the most conspicuous example. In these mines hot springs have been encountered at depths below 1,000 feet, and a water flow approximating 8,000 gallons per minute represents the drainage from the rock masses of Mount Davidson within the area tapped by the mines. In the Eureka district in central Nevada water was encountered in the mines. In many of the other mining districts water in greater or less amounts has been encountered with depth.

EXTENT, DISTRIBUTION, AND CHARACTER OF THE ROCKS OF THE BASIN REGION.

Volcanic rocks distinguish the basin region from other regions of the West. In order to get some idea of the distribution of the different rocks in the basin region, measurements were made upon the geological map of the Truckee folio, upon maps Nos. 4 and 5 of the Fortieth Parallel Survey atlas, and upon Ball's map of southwestern

Nevada and eastern California. The areas represented by each formation were measured by a planimeter and the proportion of the whole area determined. The results of these measurements are given in Table IX. (See Appendix.) In the following summary the various volcanic and Plutonic rocks have been grouped: Rhyolites and granites; andesite basalts, diabases, and diorites; metamorphics, limestones, and sedimentary and water areas.

Areal distribution of rocks in the Great Basin region.

Rock.	Truckee quadrangle.	Fortieth Parallel Survey Atlas.		Ball's map of southwest Nevada and eastern California.
		No. 5.	Nos. 4 and 5.	
Rhyolite and granite	22.0	18.8	[1] 22.5	21.5
Basalt, diabase, and diorite	45.1	14.2	25.5	11.5
Metamorphic	6.15			
Limestone				12.1
Sedimentary and water	26.8	67.0	53	54.9

[1] Assuming area of rhyolite and trachyte is one-half rhyolite and one-half andesite.

The total areas occupied by igneous rocks are as follows: For the Truckee sheet, 67 per cent; for map No. 5 of the Fortieth Parallel Survey, 33 per cent; for maps Nos. 4 and 5 together, 48 per cent; for Ball's map, 33 per cent. The Truckee sheet may be considered as descriptive of an area in which igneous rocks dominate. This area would not be a fair representation of the whole basin region. The results obtained from the other three measurements indicate a range of 33 to 48 per cent. Which of these two measurements could be taken as representative of the basin region as a whole is a matter of doubt. Probably 40 per cent would be a fair figure to indicate areal distribution of igneous rocks in the basin region. This would leave 60 per cent for sedimentary and alluvial formations. On this basis some 84,000 square miles of the basin region is occupied by igneous rocks. We may assume that acid rocks take somewhat less than one-half of this area and basic rocks somewhat more than one-half.

The chemical composition of the rocks of the basin region has been determined by averaging the reported analyses of the various rocks. Table X (Appendix) gives the results of this study.

SOURCES OF SALINES.

The salines of the basin region consist of mixtures of chlorides, sulphates, carbonates, bicarbonates, nitrates, and borates of sodium, potassium, calcium, and magnesium. Lithium, alumina, ferric oxide, silica, bromine, iodine, phosphoric and arsenious acids have been detected in small amounts in the brines and waters of the basin. Alumina, ferric oxide, and silica are almost invariably found in small amount in river and lake waters and associated with saline crusts. Spectroscopic examination shows lithium in small quantity to be widely associated with saline material.

Salines result from the disintegration and decomposition of igneous and sedimentary rocks, from the decomposition of alluvial and detrital fills, and from the waters of springs of deep-seated origin. During Quaternary times the basin region was the scene of numerous volcanic eruptions. How important these were as contributors to the salines can not now be told, but they must have been not unimportant sources of saline material.

IGNEOUS ROCKS.

In a previous section it has been shown that approximately 40 per cent of the basin area is covered by igneous rocks, and that somewhat less than one-half of this area is represented by rocks of an acid type, while somewhat more than one-half is represented by rocks of a basic type. The composition of the more important types of igneous rocks is given in Table X (Appendix). From the figures in this table the following table has been calculated:

Chemical composition of the more important basic and acidic rocks.

Constituents.	Type, acid.	Type, basic.	Constituents.	Type, acid.	Type, basic.
Base:	*Per cent.*	*Per cent.*	Acid:	*Per cent.*	*Per cent.*
MgO	1.05	4.52	S	0.370	0.066
CaO	2.15	6.33	Cl	.015	.068
Na_2O	3.35	3.29	CO_2	.160	.326
K_2O	4.10	2.09	SO_3	.035	....
Total	10.65	16.23	P_2O_5	.145	.240
			Total	.735	.700

The table gives the average percentage composition of acid and basic divisions of the igneous rocks. Only those constituents have been included which might be expected to contribute to the bases and acids of salines.

Hydration and carbonation are the two important processes by which igneous rocks are decomposed. The rate at which decomposition proceeds is dependent upon the rate of disintegration, as well as upon the intensity of hydration and carbonation. Hydration and carbonation are dependent for their intensity upon climatic conditions. Disintegration depends upon extremes of temperature, the physical nature of the rock, the activity of erosion, and the rate of decomposition of the rock constituents. Disintegration and decomposition proceed simultaneously. Under arid climatic conditions, such as pertain in the basin region, disintegration is dominant and decomposition is measurably less than under humid climatic conditions. This fact has been pointed out by a number of investigators—Van Hise, Merrill, Hilgard, Clarke. Further confirmation of this fact may be easily obtained by petrographic examination of the alluvial material taken from the aprons bordering the basin ranges. Comparatively fresh particles of feldspar may be found even in the finer silts of the central parts of the basin.

The extent to which the igneous rocks of the basin region have been decomposed, and the constituents and proportion of each which might be expected to form accessions to the salines, have not been made the subject of special study. In a general way it might be said that the amount of rock decomposition in this region is nominal. Pre-Tertiary igneous rocks (in the main granites and diorites), where exposed, are noticeably decomposed. The older Tertiary volcanics (andesites) are also decomposed to a considerable extent. This is particularly noticeable in the areas in which hydrothermal activity was once dominant. In such areas decomposition extends locally to comparatively great depths and the rock alteration is in many cases profound. In the basin region there are some 350 mining districts. Each of these may be considered to have been in the past the locus of more or less hydrothermal action. The aggregate altered rock area of these districts is not known, but it must constitute an extremely small part of the total basin area and be therefore relatively unimportant as a source of saline material. Late Tertiary rhyolites and Quaternary igneous rocks are often only superficially decomposed, except in those regions where hot springs have continued their activities to comparatively recent times.

Humid conditions exist only on the highest mountain ranges and consequently the areas exposed to weathering under the most favorable conditions for decomposition must constitute a relatively small part of the total. Over a large part of the area exposed to weathering influences the conditions in the Great Basin are such as to produce decomposition at a comparatively slow rate at the present time. That this was not always the case has been shown by the investigations of Gilbert and Russell. It is to be particularly noted that in Quaternary times climatic changes were numerous and humid conditions alternated with arid conditions. During the period of Quaternary lake development the rock decomposition must have proceeded at a very much more rapid rate than under present conditions. Consequently a greater amount of saline material must have been contributed and have been deposited in the basins.

The minerals constituting igneous rocks are attacked at different rates. Clarke states: "The pyroxenes and amphiboles yield most readily to waters; then follow the plagioclase feldspars, then orthoclase and the micas, with muscovite the most resistant of all. Even quartz is not quite insoluble, and the corrosion of quartz pebbles in conglomerates has been noted by several observers. Among the common accessories, apatite and pyrite are most easily decomposed, magnetite is less attacked, and such minerals as zircon, corundum, chromite, ilmenite, etc., tend to accumulate with little alteration in the sandy rock residues."

This conclusion no doubt applies to conditions more nearly approaching humid than arid. We should expect under arid conditions, that the more insoluble minerals would be relatively less affected than the more soluble. Orthoclase and muscovite are the two chief potash-bearing minerals. They are also the most resistant to weathering. This, together with the fact that the acid rocks which contain these minerals are relatively less abundant than the basic rocks which contain the plagioclase feldspars, would lead one to conclude that potash would be found in the salines in much smaller quantities than soda. Van Hise, in discussing the decomposition of orthoclase, shows that this mineral may be altered into kaolin with the liberation of all of the potash in the form of potassium carbonate, or into muscovite with the liberation of only two-thirds of the total potash as potassium carbonate. His reactions are:

$$2KAlSi_3O_8+2H_2O+CO_2=H_4Al_2Si_2O_9+4SiO_2+K_2CO_3.$$

$$2KAlSi_3O_8+H_2O+CO_2=KH_2Al_3Si_3O_{12}+6SiO_2+K_2CO_3.$$

The relative importance of these two reactions can not, for obvious reasons, be stated. Both take place in nature. Probably in regions of hydrothermal activity the alteration to kaolin is more often found, while in regions of simple weathering the reverse is more often the case.

From the foregoing table it is seen that the soda content of basic is only slightly less than for acidic rocks. While the potash content of basic is about one-half that of the acidic rocks, the greater susceptibility to weathering of the basic rocks would lead us to conclude that the larger proportion of soda would be liberated from these rocks rather than from acidic rocks.

Lime and magnesia are liberated by decomposition but tend to pass into insoluble compounds more quickly than either potash or soda; consequently, we should expect to find them less abundant in salines.

The acid constituents of igneous rocks are relatively less abundant than the basic. Weathering would liberate these, and the abundance of oxygen present in the zone of weathering would convert the sulphur into sulphuric anhydride. This is also indicated by the comparative absence of reducing substances shown by the scanty vegetation of the basin. The chlorine, carbonic acid, and sulphuric acid would combine with whatever bases were present to form chlorides, carbonates, and sulphates.

The phosphoric acid, if liberated as soluble phosphate, would quickly pass into one of the many insoluble phosphates. Phosphoric acid is found in the salines only in small quantities and can not be considered as an important constituent of these substances.

Merrill, in discussing the decomposition of igneous rocks, presents the results of a number of studies and has endeavored to show what proportion of the original rock has been lost in the form of soluble compounds. It is evident that a mere comparison of analyses of weathered versus fresh rocks is inadequate. While it is generally true that the percentage of alkalies present in material resulting from weathering is less than the percentage in the undecomposed rock, still we have many examples where apparently the percentage composition has been unchanged, or the percentage of the alkalies has been increased. This is due to the fact that as the rock weathers its volume and weight change. If it were possible to determine the weight of fresh rock and the weight of residual material (soil) resulting from weathering, we could determine the proportionate loss of the constituents. This, for obvious reasons, can not be done. By assuming one constituent as constant, and that the most insoluble one, Merrill[1] has calculated the proportional loss of constituents due to weathering. From 10 examples of igneous rocks given by this author I have calculated the average percentage losses. The following table gives these for alumina, ferric oxide, lime, magnesia, potash, and soda:

Percentage loss of constituents from igneous rocks caused by decomposition.

Constituent.	Mean loss humid region.[2]	Estimated for arid regions.[3]	Ratio, humid-arid.[4]
	Per cent.	*Per cent.*	
Al_2O_3	14.17	7.8	1.8
Fe_2O_3	32.84	18.2	1.8
CaO	66.9	5.3	12.6
MgO	64.7	10.4	6.2
K_2O	62.1	19.0	3.3
Na_2O	72.0	24.8	2.9

[1] Rocks, Rock Weathering, and Soils, p. 188. Merrill.

[2] Calculated averages from examples of igneous rock decomposition given by Merrill. Merrill's examples include granites, phonolites, syenite, diabases, basalts, diorites, and andesites. Rocks, Rock Weathering, and Soils, pp. 185–208, Merrill.

[3] Calculated by dividing percentages of first column by ratios given in last column.

[4] Calculated from data given by Clarke of average analyses of soils of humid and arid regions (Bul. 491, U. S. Geol. Survey, p. 467). Ratio is percentage of constituent in acid-soluble portion of soils from arid region divided by percentage of constituents in acid-soluble portion of soils from humid regions.

The results given are for humid conditions. We have no examples of a similar nature for arid conditions. A rough approximation may be made from the comparison of soils of arid regions with those of humid. Clarke[1] gives average analyses of a number of soils for both climatic conditions. From these we can obtain the ratio of one constituent in the average of soils from arid regions to the same constituent in average of soils from humid regions. These ratios are given in the foregoing table. If we assume that the proportional loss of a constituent from rocks in arid regions is the product of the proportional loss in humid regions and the reciprocal of the ratio, the results in second column of above table are obtained. No high degree of accuracy can be vouched for these results.

The following table has been calculated from the tables immediately preceding, and gives, perhaps, a better idea of the measure of igneous rock decomposition and the liberation of soluble constituents. The unit is taken as 100 pounds and only the more important bases and acids have been calculated. The acid constituents, with the exception of phosphoric acid, have been assumed to be entirely liberated.

Contribution from 100 pounds of original rock.

	Acid type.		Basic type.			Acid type.		Basic type.	
	Pounds constituent in 100 pounds.	Pounds contributed by weathering.	Pounds constituent in 100 pounds.	Pounds contributed by weathering.		Pounds constituent in 100 pounds	Pounds contributed by weathering.	Pounds constituent in 100 pounds.	Pounds contributed by weathering.
MgO	10.50	0.156	4.52	0.470	S	0.370	0.370	0.066	0.066
CaO	2.15	.114	6.33	.335	Cl	.015	.015	.068	.068
Na_2O	3.35	.831	3.29	.816	CO_2	.160	.160	.326	.326
K_2O	4.10	.779	2.09	.397	SO_3	.035	.035	....	....
					P_2O_5	.145	....	.240	....
Total	10.65	1.880	16.23	2.018	Total	.725	.580	....	.460

SEDIMENTARY ROCKS.

The pre-Tertiary sedimentaries of the basin region are not important sources of saline material. Limestones are abundant and contribute to the lime compounds associated with salines. The gypsum deposits of the Triassic are and have been an important source of this compound. From Table X (Appendix), giving the average analyses of Great Basin rocks, it is seen that limestones contain 0.51 per cent alkalies. Merrill[2] shows that for weathering under humid conditions a limestone loses 63 per cent of the alkalies. If we take one-third of this as representing the conditions for an arid climate, we would have 21 per cent of 0.51, or about one-tenth of a pound of alkali per 100 pounds of fresh rock. The slates and quartzites contain small quantities of alkalies, but weather much less rapidly than either igneous or calcareous rocks. By their decomposition small amounts of bases are contributed to salines, but, on the whole, we must consider them far less important as a source of salines than other rocks.

The Tertiary lake beds constitute one of the most important sources of saline materials outside of the igneous rocks. They consist of limestones, shales, diatomaceous beds, slates, and sandstones. Interbedded and often commingled are salines of which common salt, sodium sulphate, gypsum, and boric minerals predominate. The disintegration of these beds liberates saline material, while the decomposition of the residual portion contributes an additional amount. As these beds are comparatively soft, they would erode rapidly, and, no doubt, in late Tertiary and Quaternary times they contributed a large proportion of the detrital filling of the present basins. The table following, showing partial analyses of lake-bed material, will give some idea of its chemical nature.

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[1] Bul. No. 491, U. S. Geol. Survey, p. 467.

[2] Rocks, Rock Weathering, and Soils, Merrill, pp. 217–19; Mean of Percentages for K_2O and Na_2O.

Analyses[1] of material from lake beds northeast of Mina.

Constituents.	Sample No.—								
	1	3	4	5		7	8	9	12
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Insoluble residue	14.70	56.40	10.00	24.70	69.70	79.60	77.90	39.20	46.00
CaO	44.06	17.24	45.80	38.42	4.55	2.33	1.95	29.92	26.67
MgO	.58	.75	1.12	.40	2.55	.79	.76	.94	.54
K_2O (total)	.24	1.12	.38	.46	1.81	3.08	1.91	.90	1.46
Na^2O (total)	.25	1.47	1.23	1.28	2.50	3.00	5.47	2.05	1.54
Cl	.29	.18	Tr.	.19	.90	.49	.33	.12	.14

[1] Alkalies determined by Cullen; others determined by Young.

All except sample No. 1 contain traces of P; all contain acid-soluble Al_2O_3 and Fe_2O_3.

The samples were taken from different beds. My examination failed to show water-soluble carbonates and sulphates, and I found only traces of water-soluble potash. The principal soluble salt was sodium chloride. Other analyses of these lake beds have been reported and sodium chloride noted. The material other than that of a calcareous nature consisted of volcanic glass and tuffaceous particles of a volcanic nature. Microscopic examination showed much volcanic glass. The examination also indicated that most of the material, excepting calcium and magnesium carbonates, was of a wind-blown nature and had been deposited in shallow, brackish lakes in which calcium and magnesium carbonates were being laid down.

The Quaternary lake beds are of considerably less importance than the Tertiary. They contribute some saline material to the present drainage system, but as these beds are in the main sands and silts with little visible saline material, they may be regarded as of minor importance. Russell[1] reports lacustral material containing as much as 1.17 per cent sodium chloride. In this connection it should be noted that the material obtained from the 985-foot bore, sunk by the Geological Survey in Carson Sink through recent and Lahontan formations, failed to show any brines or solutions of marked saline content. Petrographic examination of Lahontan Lake bed sedimentaries shows comparatively little decomposition of the feldspars.

ALLUVIAL AND DETRITAL MATERIAL.

The heterogeneous material constituting the valley fills comprises more than 50 per cent of the whole basin area. As this material is in a more or less finely divided condition and is subject to the action of percolating waters, decomposition must be more or less active and a not unimportant amount of salines contributed to the present stream systems through the agency of underground and surface waters.

SPRINGS.

As has been shown in a previous chapter, numerous hot springs occur in the basin region. No very complete studies of these have been made, and comparatively few analyses have been reported. In the table which follows, I have summarized the analyses of some 16 such springs.

Analyses of hot spring waters.

Constituent.	A.	B.	C.	D.	E.	F.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Cl	58.84	56.72	58.79	35.00	38.79	20.27
SO_4	1.41	2.87	.94	4.58	14.25	34.19
S				.22		
CO_3	.90	1.05	.61	5.08	None.	Trace.
B_2O_7				8.91		
Na	33.15	34.78	30.38	30.35	31.04	29.78
K	3.19	3.33	3.76	3.79	2.69	.92
Li				.27	Trace.	
Ca	1.99	.91	4.90	.25	1.23	1.18
Mg	.24	.17	.40	.01	.04	.04
As				.12		
Al_2O_3			.82	.01	.04	
SiO_2	.28	.17	.20	11.41	[1] 11.92	[2] 13.62
	100.00	100.00	100.00	100.00	100.00	100.00
Total solids on evaporation (parts per 100,000)	3,067	2,443	2,330	285	249.5	102.1

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[1] Quaternary History of Mono Valley, 8th Annual Report, U. S. Geol. Survey, p. 307.

[2] Calculated as SiO_3.

Analyses of hot spring waters—Continued.

Constituent.	G.	H.	I.[1]	J.[1]	K.[1]	L.[1]	M.[1]
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Cl	20.25	10.98	2.63	9.74	Trace.	47.93	47.53
SO_4	32.97	15.13	4.04	6.96	8.21	11.25	8.15
S	....	....	....	....	....	....	....
CO_3	Trace.	27.97	23.84	18.08	25.6	.67	1.36
B_2O_7	....	....	....	....	....	....	....
Na	30.03	29.56	12.83	10.67	2.25	32.63	31.92
K	1.61	3.05	2.12	5.33	5.15	2.70	2.80
Li	Trace.	....	....	....	....	....	....
Ca	3.10	2.84	5.96	5.34	11.11	2.48	2.10
Mg	.29	2.92	2.02	2.55	Trace.	Trace.	Trace.
As	....	....	....	....	....	....	....
Al_2O_3	....	.09	....	....	....	....	....
SiO_2	[2] 11.75	[2] 7.46	....	....	....	....	....
	100.00	100.00	....	....	....	....	....
Total solids on evaporation (parts per 100,000)	118.3	206.9	99.2	43.2	62.0	44.40	428.0

[1] Analyses not complete. Percentages based on solids on evaporation.

[2] Calculated as SiO_3.

A. Water from hot salt spring near bathhouse, Silver Peak, Nev. R. Dole, Bul. No. 530, U. S. Geol. Survey, p. 16.

B. Water from hot salt spring at northeast end of marsh, Silver Peak, Nev. R. Dole, Bul. No. 530, U. S. Geol. Survey, p. 16.

C. Utah Hot Springs, 8 miles north of Ogden, Utah. Analysis by F. W. Clarke. Clarke, Bul. No. 491, U. S. Geol. Survey, p. 172.

D. Steamboat Springs, Nev. Analysis by W. H. Melville Clarke. Bul. No. 491, U. S. Geol. Survey, p. 175

E. Hot Springs, Hot Spring Station, Central Pacific Railway. Analysis by T. M. Chatard, Russell, Monograph U. S. Geol. Survey, No. 11, p. 49.

F. Schaffer's Spring, Honey Lake, Nev. Analysis by T. M. Chartard, Russell, Monograph No. 11, U. S. Geol. Survey, p. 51.

G. Hot spring, near Granite Mountain, Nev. Analysis by T. M. Chatard, Russell, Monograph No. 11, U. S. Geol. Survey, p. 53.

H. Warm spring, Mono Lake. Analysis by T. M. Chatard, Russell, 8th Annual Report, U. S. Geol. Survey, p. 288.

I. Paradise Valley Spring, Nev. Analysis by J. A. Cullen. This spring contains hydrogen sulphide.

J. X L spring, Oregon Lake Region. Analysis by J. A. Cullen.

K. Hot springs, in Thousand Springs Valley, 30 miles northeast of Wells, Nev. Analysis by J. A. Cullen.

L. Boiling spring, 0.75 mile northwest of Gerlach, Nev. Sample by W. S. Palmer. Analysis by J. A. Cullen.

M. Mean analyses of 4 spring waters taken one-fourth mile northeast of Gerlach, Nev. Temperature of waters from 61° to 90° F. Samples by W. S. Palmer. Analyses by S. C. Dinsmore.

In three of these spring waters the total solids exceed 1,000 parts per 100,000 of water, or over 1 per cent. The highest of these contains some 3 per cent total solids. The remainder contain from 0.1 to 0.8 per cent total solids. In seven of these waters chlorides predominate, while in the others chlorides and sulphates are about equally divided. In three of the waters only are carbonates conspicuous. Bicarbonates are present in seven cases. The average ratio of sodium to potassium is 10.9. In three cases the sodium-potassium ratio is notably low. The lime, magnesia, and silica are generally low. In the case of the Utah Hot Springs and the warm springs of the Silver Peak district the lime content is high, while in the case of the Steamboat Springs and hot springs of the Central Pacific Railroad the silica is high. In only one case has boric anhydride been noted.

Hot springs contribute to the salines of the basin, but it is believed that their total contribution must be small, as the flow from such springs is in the aggregate not very large, while the saline content is usually quite small. Perhaps all the hot springs of the basin would not contribute an amount of saline material equal to that from a fair-sized stream. How important the contributions to saline material in past geological ages from this source were we can not conjecture.

QUATERNARY AND RECENT VOLCANIC ACTIVITY.

Extinct craters are not uncommon in the basin region. The centers in which these cones are to be found are Lassen County, in the vicinity of Mono Lake, and in the vicinity of Great Salt Lake. In these three localities many cones have been described. In the Carson Sink, Big and Little Alkali Lakes have been determined to be the craters of extinct volcanoes. Northeast of Blair, in the Silver Peak district, Nev., is a large cone. East of milepost 48 on the road between Goldfield and Rhyolite are two cones, while southeast of Rhyolite in Crater Flat is another. In Death Valley are evidences which point to the possible existence of recent vents. In Owens River Valley is also a cone. In addition to the volcanic cones many recent (late Quaternary) lava flows, which undoubtedly originated from fissures, are to be noted.

While we have no evidence at present as to the amount and kind of saline material in the ejecta of these cones and fissures, from our knowledge of volcanic eruptions at present taking place we must conclude that a considerable part at least of the saline material at present in the basin came from volcanic sources. Chlorine, sulphuric acid, chlorides, and sulphur compounds are conspicuous in the gaseous and solid ejecta of volcanoes. Much of the chlorine that we find compounded with sodium undoubtedly originated from volcanic activity.

ATMOSPHERE.

From the atmosphere, important contributions of carbonic acid gas and, to some extent, chlorine, chlorides, and nitrogen compounds are being made. Wind erosion is undoubtedly responsible for the return of some of the saline material from the playas to the mountain ranges.

REACTIONS IN THE ZONE OF WEATHERING.

REACTIONS OF SOLUTION.

The products of disintegration and decomposition in the zone of weathering may be divided into three groups—undecomposed rock fragments, partially decomposed rock fragments, and products of complete[1] rock decomposition. The last group may be divided into soluble and insoluble products. Of these the former would consist of alkalies and alkaline earths, together with acid radicals, chlorine, sulphuric anhydride, carbonic and bicarbonic, nitric, boric, and phosphoric; the latter would consist of kaolinite, muscovite, quartz, talc, zeolitic minerals, limonite, calcite, and chlorite. Between the alkalies and alkaline earths and the acid radicals certain important reactions would take place. The relative abundance and kind of bases and acid material would determine these reactions. The solubilities of the more important constituents are given in the following table:

Solubility of important constituents of decomposition product.

Basic element.	Chloride.	Sulphate.	Carbonate.	Bicarbonate.	Nitrate.	Borate.	Phosphate.
Sodium	Soluble.	Soluble	Soluble	Soluble	Soluble.	Soluble.	Soluble.
Potassium	do	do	do	do	do	do	Do.
Calcium	do	Insoluble	Insoluble	Soluble to slight extent.	do	Slightly soluble.	Insoluble.
Magnesium	do	Soluble	do	do	do	Insoluble.	Do.

It is evident that in a system consisting of all chlorides and nitrates of the bases named all of the compounds would be soluble and only in the case of their concentrated solution would any salts separate out. It is apparent that the latter condition would rarely be present in the zone of weathering. In a system of chlorides, sulphates, carbonates, bicarbonates, nitrates, borates, and phosphates of sodium and potassium no reactions resulting in insoluble compounds could take place. In a system of chlorides and sulphates, lime would be the only base precipitated as a sulphate. This is indicated by the fact that gypsum is not an infrequent mineral in the zone of weathering, and its presence is no doubt due in part to reactions of this nature. The most common system that we find includes the chlorides, sulphates, carbonates, and bicarbonates of sodium, potassium, calcium, and magnesium. In this system calcium and magnesium would be thrown down as comparatively insoluble carbonates and calcium also as gypsum. We would expect the solution resulting to contain chlorides, sulphates, carbonates, and bicarbonates of sodium and potassium. In a system in which calcium and magnesium predominate we would expect to find mainly soluble chlorides, as all carbonic acid and sulphuric acid, except that required to saturate the system, would be thrown down by calcium and magnesium.

The analyses of waters coming from the zone of weathering invariably show small quantities of silica, ferric oxide, calcium carbonate, calcium sulphate, and alumina.

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[1] The word "complete" is used in a restricted sense.

These are all compounds of very low solubility, and, as practically all are present abundantly in the zone of weathering, we may consider the solution as being saturated, or nearly saturated, with respect to these compounds. With the more soluble compounds it is unusual, except very locally, to have conditions in the zone of weathering which would lead to saturation.

Wind and water are the two agents concerned in the movement of the products of the zone of weathering. Even though the basin region has a scanty rainfall, water is by far the more important agent. Water dissolves the soluble constituents and carries away in suspension the finely comminuted products of disintegration and decomposition. Heavy rainstorms and cloudbursts carry down from the mountains quantities of comparatively coarse material to be deposited upon apron slopes or even in the central portions of the playas. One has but to walk over the detrital fans in Death Valley to appreciate the prodigious erosion that has been accomplished by cloudbursts. Ravines and gullies are choked with coarse débris, which spreads out in fan-like masses at their mouths and resembles more than anything else the piles of débris resulting from hydraulic mining. One has but to experience a dust storm in Death Valley, or any portion of the basin region for that matter, to appreciate the importance of wind as an agent of erosion and deposition.

ABSORPTION PHENOMENA.

In a previous section has been pointed out the importance of the seepage water and the fact that only a small part of the rainfall is collected in streams and reaches the sinks and lakes. This fact would indicate that under present climatic conditions only a fraction of the soluble salts is collected by the run-off, while the greater part is carried away by the seepage water to be in part permanently retained by the soil and in part to be removed by underground waters. Certain reactions take place within the soil and alluvial material and the soluble salts which are carried into the seepage zone by percolating waters. These reactions are to a greater extent chemical and to a less extent physical in nature. The net result is to withdraw a portion of the saline material permanently. The reacting substances are silicates and the colloidal material of soils, and in the solution, soluble salts of sodium, potassium, calcium, and magnesium. A solution of salts carrying more or less suspended material percolates into alluvial material. The suspended material is quickly removed and is concentrated in the upper layers of the soil. The phenomena attending the reaction between soil constituents and solutions are much more complex. Cameron[1] shows that absorption accounts for the removal of a part, at least, of the soluble salts. He groups under the term absorption the mechanical inclusion of solutions, the formation of new compounds by double decomposition, and the condensation of dissolved substances on or about the surface of the absorbing medium. To the last the term absorption is given. E. C. Sullivan has summarized the literature dealing with adsorption, and from this summary the facts of special interest to this inquiry are taken.

The principal conclusions are embodied in the following quotations:

"So far as the evidence goes the action of silicates, clay, and other constituents of the earth's crust in solutions of such salts as do not dissolve in water with alkaline reaction consists in an equivalent exchange of bases. The salt is uniformly distributed between the water of colloid silica and silicates and the water of the solution. Any absorption of the salt as a whole by the solids mentioned is so slight as to have escaped positive detection. As bearing upon the latter point, it should be said that certain colloid substances, analogues to which are present in the earth's crust, do take from solution both the acid and base of the salts mentioned. Ferric and aluminum oxides and metastannic and stannic acids, for instance, take potassium sulphate from solution, while hydrated manganese dioxide takes up sulphate, chloride, or nitrate of potassium.[2]

"It may be observed that the base enters into reaction to approximately the same extent, whether it is combined as sulphate, chloride, or nitrate. So far as there is a difference, more of the base is removed from sulphate solution than from the others. On comparing chemically equivalent quantities, it is seen that ammonium is taken from solution in greatest degree, followed in order by potassium, magnesium, sodium, and calcium. As to the bases dissolved from the soil, Küllenberg's conclusion is that for the absorbed base nearly equivalent quantities of other bases, already present in the soil, have been carried over into the solution.[3]

"When the solution is alkaline in reaction, containing a soluble hydroxide dissolved as such or a salt made up of a strong base and a weak acid (as the carbonates, silicates, and phosphates of sodium and potassium), which is hydrolyzed by water with resulting formation of free alkali, its behavior with clay, soils, etc., is due largely to the presence of colloid silica or alumino-silicate, and consists primarily in the direct addition of alkali to these solids, without substitution, insoluble silicates or alumino-silicates being formed.[1]

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[1] The Soil Solution: Cameron, p. 59.

[2] Bul. 312, U. S. Geol. Survey, p. 27.

[3] Ibid., p. 16.

"The loss of an acid radical of a dissolved salt to clay, soil, etc., appears, like the loss of the base, to be due usually to the formation of an ordinary insoluble salt, such as the phosphate, carbonate, or silicate of calcium, iron, etc. Such precipitation takes place primarily from alkaline solution, because the acids that have the greatest tendency to form insoluble compounds are weak acids, whose salts are hydrolyzed by water.[2]

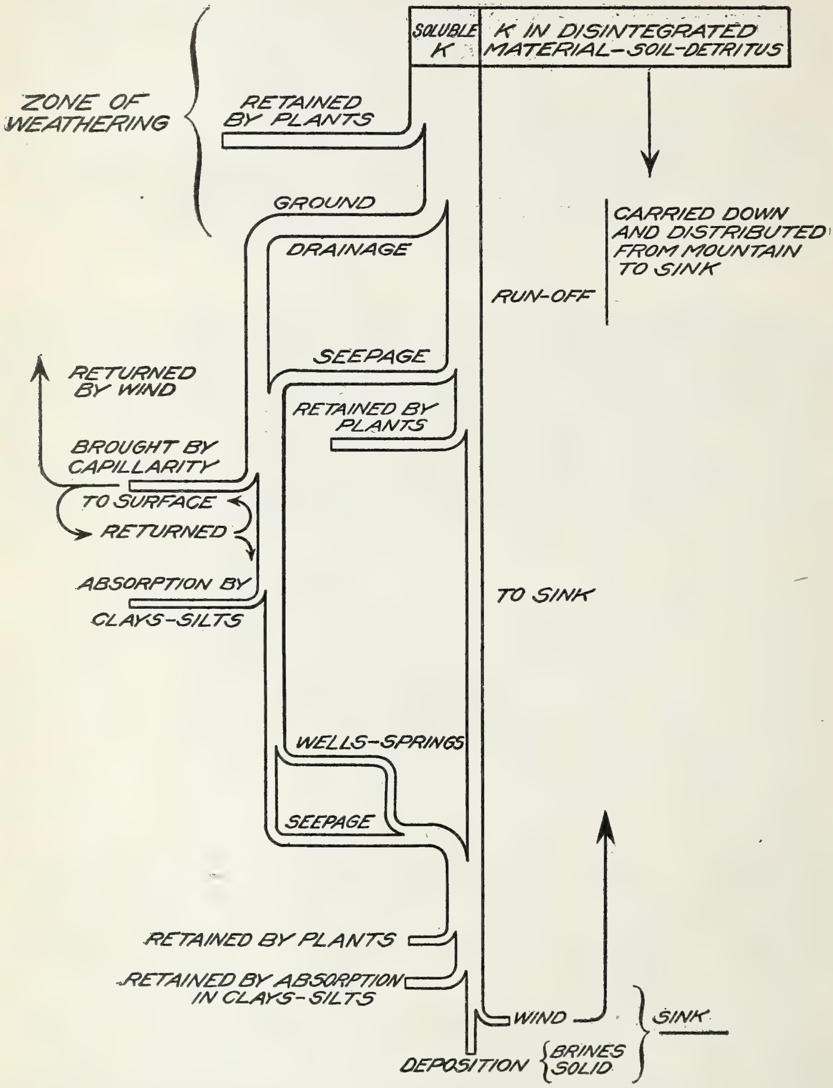

FIG. 2.—Diagram showing the factors of loss during the movement of a soluble salt from the weathering zone to the sink.

* * * "Sodium silicates and alumino-silicates are less stable in contact with water solutions than the corresponding potassium compounds. Evidence of this is

found not only in the laboratory, but also under natural conditions. The replacement of sodium in silicates by the potassium of a dissolved salt takes place far more readily than the reverse reaction. A similar reaction, although perhaps not quite so marked, exists between magnesium and calcium silicates. The transformation of a magnesium silicate by calcium chloride into calcium silicate is more difficult than the reverse change." [1]

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[1] Bul. 312, U. S. Geol. Survey, p. 28.

[2] Ibid., p. 30.

The most significant fact of absorption phenomenon is the greater susceptibility of potassium to be absorbed than any of the bases and the greater resistance of potassium compounds to the action of percolating waters. The acid radicals, with the exception of carbonic, bicarbonic, and phosphoric, are unaffected in quantity.

The restricted and irregular rainfall of the basin region would result in more concentrated solutions being received by the seepage zone, and would result, therefore, in a greater relative amount of absorption than with the less concentrated solutions of humid regions.

A further fact must be kept in mind, and that is that a considerable part of the basin area receives such a scanty rainfall that only on comparatively steep slopes do the percolating waters reach ground-water levels and add their quota of soluble material to underground circulating waters. The greater part of the intermountain area acts like a sponge and receives and retains the waters and their dissolved salts. Capillarity raises a part of the water, together with such soluble material as escapes absorption.

Vegetation also plays an important part. It is a well-known fact that plants absorb potassium salts from the soil and seepage water. The amount of potassium removed annually in this way from ground waters must be large.

We are justified in the conclusions that in the basin region a large part of the soluble salts is retained in the interstitial or pore spaces of the soil; a part of the soluble material is changed to insoluble, and potassium is more likely to be retained and in greater relative amount than any of the other bases; a precipitation of the more insoluble carbonates, such as lime and magnesia, takes place in the upper part of the soil; that the stronger acids, such as chlorine, sulphuric anhydride, nitric, and boric (excepting sulphuric and boric in the presence of soluble lime salts) are practically undiminished by absorption phenomena. Combined with various bases they either remain in the soil or are leached away in the ground water.

Soluble salts reach the sinks or lowest parts of the intermountain areas in two ways—by underground waters which gravitate to the low points and by the run-off waters which accumulate in the same places. It is evident that in the passage of the seepage water to the sink absorption continues and only a final residuum, which may be only a small part of the original total of soluble salts, reaches the sink. The run-off waters are diminished on their way to the sink by seepage waters with consequent loss of a part of the dissolved salts. Figure 2 illustrates the various losses which we may expect in the movement of a soluble salt from the weathering zone to the sink. I have taken potassium as the base to best illustrate the point. The quantitative side of the problem can not be determined and consequently the figure does not involve this feature.

The case for sodium would be simpler than for potassium. Little or none of this base would be retained by plants or by chemical absorption, and the only loss would be that portion retained and brought by capillarity to the surface or retained simply by the soil. The greater part of the sodium, either as sulphate or chloride, would eventually reach the sink.

The case for lime and magnesia is also a simple one. Only that portion in the run-off waters would reach the sink. The remainder would be found distributed from and within the zone of weathering to the sink. The greatest part would be nearest the belt of weathering. A nominal amount would reach the sink through the agency of ground waters.[2]

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[1] Bul. 312, U. S. Geol. Survey, p. 22.

[2] Calcareous hardpans are not infrequently found in the Great Basin. In the vicinity of Las Vegas, Nev., there is an especially good illustration of the development of a thick layer of calcareous material. This in some places forms the surface and in other places is covered by a thin soil. The rocks of the neighboring mountains are sandstones and limestones. An analysis of this hardpan shows the following (analysis by J. A. Cullen, Bureau of Soils):

	Per cent.
Insoluble	7.6
Ferric oxide and alumina	.46
Lime	37.20
Magnesia	12.65
Total potash	.30
Total soda	.39
Sulphate radical	.03

I have also noted many instances where the material of gulch dumps in the basin mountains has been cemented together by calcium carbonate.

In the alluvial fans it is not uncommon to find the material removed by the burrowing of small animals to be coated by calcium carbonate.

The factors influencing absorption are the rate of movement of underground waters, the concentration of solutions, the chemical nature of salines and salts, the distances to be traversed to outlet if spring, or to sink if there is no surface outlet. In the case of saline solutions retained locally the time factor is greatly increased and, consequently, absorption may proceed to practical completion. The conditions in any one case are so variable and the difficulty of definitely determining the quantities involved so great that we can not determine the extent of absorption. Evidence goes to show that potassium in some cases is almost completely retained. The comparison of underground waters with surface waters and the comparison of soils from humid and arid regions can, in a measure, be relied upon to show the character of the changes. The two succeeding sections deal with these subjects.

UNDERGROUND AND SURFACE WATERS.

In Table XI (Appendix) are given a number of analyses of well and spring waters from the Nevada experiment station records, obtained through the courtesy of S. C. Dinsmore. Accompanying are two tables, Nos. XII and XIII (Appendix), giving analyses of waters in Death Valley and Amargosa regions. The average ratios of sodium to potassium are as follows:

	Ratio.
Well and spring waters in western Nevada	43. 1
Waters from Death Valley	47. 4
Waters from the Amargosa	9. 9
The Truckee, Humboldt, and Weber Rivers	3. 6
The basin lakes	20. 0

Seepage originates in part from run-off waters. The absorption of potassium would be indicated by a greater ratio of sodium to potassium in underground waters as compared to the run-off waters. This is indicated by the above ratios. The ratio for the basin lakes is intermediate between these for ground and surface waters. This is to be expected, since the lakes receive seepage as well as run-off waters.

SOILS OF HUMID AND ARID REGIONS.

Clarke[1] gives the average analyses of a number of soils from humid and arid regions. From these analyses the sodium-potassium ratio has been obtained and for purposes of comparison the same ratio for the igneous rocks of the basin is given.

Ratio of sodium to potassium in soils and rocks.

Ratio of potassium in—	
Humid soils	0. 39
Arid soils	. 31
Acid rocks	. 78
Basic rocks	1. 50
Mean, acid and basic	1. 14

The figures obtained do not give a fair basis for comparison. In the case of the soils the sodium and potassium are determined in the solutions obtained by decomposition with hydrochloric acid. In the case of the analyses of the rocks the sodium and potassium represent the total percentage of each in the rock. If we assume that the insoluble residue obtained from the humid or arid soil would be of practically the same constitution the ratios would be of some value in indicating absorption. The arid soils show a greater proportion of potassium than the humid. If our assumption is correct, this is due to absorption. It may also be due to differences in the degree of decomposition. Comparing the soils with the rocks indicates the removal of sodium at a much greater rate in the weathering process than potassium. If we compare the percentage composition of the mean arid with the mean humid soil, we find the following interesting ratios:

Ratio arid to humid percentages of constituents soluble in hydrochloric acid.

Acid soluble:	
Soluble SiO_2	1. 7
Al_2O_3	1. 8
Fe_2O_3	1. 8
MgO	6. 2

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[1] Bul. No. 491 U. S. Geol. Survey, p. 467.

Acid soluble—Continued.	
CaO	12.6
Na_2O+K_2O	3.2
P_2O_5	1.0
SO_3	.8
Total acid soluble:	
Arid (per cent)	29.5
Humid (per cent)	16.0

These ratios indicate a much greater proportion of soluble material on the whole in the arid than in the humid soils. The greater proportion of soluble silica and acid soluble alumina would indicate more favorable conditions for the absorption of alkalies in the case of arid soils. The greater proportion of alkalies and alkaline earths indicates that absorption either by chemical reaction or by simple retention of soluble salts is a marked feature of arid soils.

While absorption by chemical reaction is of undoubted importance, absorption by retention of soluble salts is of much greater importance and is characteristic of the soils of the basin region. Whitney and Means state [1] that the soluble salts for soils of a sandy nature approximate 50 pounds per acre-foot (0.0015 per cent), for heavy soils from 3,000 to 4,000 pounds per acre-foot (0.09 to 0.12 per cent), and the average amount for soils of humid areas somewhat less than 1,000 pounds per acre-foot (0.03 per cent). Hilgard [2] states that very few of the upland soils in the arid regions of California contain less than 2,000 to 2,500 pounds of soluble salt per acre in the first 4 feet. In the soils of the lowlands the content of soluble salt must be considerably greater. No general numerical statement can be made for the soils of the basin region, but we know that in many cases the amount of soluble salts must be many times greater than that contained in the soils of humid regions. Table XIV (Appendix) gives the content and chemical composition of the soluble salts for a number of soils in the basin region. I have taken most of these from three widely separated localities. The first set are from soils in the vicinity of Fallon, Nev.; the second from soils in the vicinity of Salt Lake, Utah; and the third from southern Oregon. The average content of soluble salts for the Fallon soils is 1.23 per cent and for the Utah soils 1.8 per cent. It should be noted that the examples given are undoubtedly from localities more or less heavily impregnated with soluble salts. The average for the Fallon area can be obtained from figures presented in the advance sheets of the field operations of the Bureau of Soils, 1909.[3] The content of alkali and the acres affected in each instance are given:

82,624 acres contain less than 0.2 per cent alkali.
38,784 acres contain from 0.2 to 0.4 per cent alkali.
8,768 acres contain from 0.4 to 0.6 per cent alkali.
8,128 acres contain from 0.6 to 1.0 per cent alkali.
12,096 acres contain over 1 per cent. The average content for 150,400 acres is 0.4 per cent.

While the results for the Fallon section can not be taken as representative of the basin region, still it can be said that they show the results for one important area. The conditions in other portions of the basin, and particularly south of the Fallon area, can not be much different. In fact, as we proceed south the evidences of soluble salts become more and more common. Many of the flat valleys which characterize southern and central Nevada show that the conditions are very favorable for the retention of the soluble salts. The physical conditions influencing the retention of salts by and their movement in soils merit some discussion and the succeeding section covers this subject.

RETENTION AND MOVEMENT OF SOLUBLE SALTS BY SOILS OF ARID REGIONS.

The factors controlling the retention of soluble salts are underground drainage, character of the soil, slope of soil surface, and rainfall. With good underground drainage, even under arid conditions, there is a gradual movement downward of the soluble salts. Underground drainage is dependent upon the character of the soil and the slope of the soil surface. With compact, heavy soils much seepage water is retained and drains away very slowly, or not at all. Capillarity acts in fine-textured soils to return the ground water, in some cases back to the surface, or in others to some intermediate level. With porous, open, and coarse-textured soils capillarity may act to a small extent, but only very locally, and the seepage water drains speedily away. Where impervious layers occur, ground water may be retained and by evaporation leave its burden of salts within the soil at varying depths. Where soil surfaces are sloped, underground drainage is facilitated, and, if the soils are not too coarse textured, or capillarity not an important factor, the soluble salts are drained away and deposited in the level portions of the valleys.

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[1] Bul. No. 14, Bureau of Soils, p. 22.
[2] Bul. No. 35, Bureau of Soils, p. 13.
[3] Soil Survey of the Fallon Area, Nevada, p. 43.

With moderate rainfall salines are distributed in sandy soils with the least proportion at the surface and greater amounts or accumulations at intermediate points. Under arid conditions these accumulations would be nearer the surface, and in regions of extreme aridity would be very close to and even at the surface. With heavy soils (slow movement of ground water) the accumulations of salines would be nearer the surface for moderate rainfalls and much closer to the surface for small rainfalls than for the porous soils.

Means [1] discusses the conditions under which alkali salts move within the soil and his conclusions are pertinent here. He states that—

(1) "Movement of alkali salts is caused by diffusion of the salt mixture;
(2) "By the force of gravity in moving the salt mixture downward;
(3) "By surface tension or capillary action which moves the salt mixture in any direction."

Means considers that the effects of the diffusion are practicably negligible. The second and third causes may best be placed in his words:

(2) "*Force of gravity.*—When water is applied to the surface of the soil the force of gravity, assisted by surface tension, pulls the water down into the capillary spaces. Soils will hold a certain percentage of water by capillary forces alone, and any excess over this percentage will drain away. This excess is called gravity water. When the surface of the ground is flooded, both surface tension and gravity act in pulling the water downward. Since the rate of flow of water through capillary spaces depends upon the size of the space, the flow through the large capillary spaces, root holes, worm borings, and animal burrows is very much greater than that through the true capillary spaces. When water is applied, the downward movement by gravity is almost entirely through the larger noncapillary spaces, while the true capillary spaces are filled by surface tension from the noncapillary spaces. In this way the salt which is dissolved by the descending water is probably to some extent drawn back into the capillary spaces, where there is very little downward movement, and remains there, only escaping out into the channels of downward movement by diffusion. The amount of salt which is washed downward by a heavy flooding is therefore not so great as would be expected.

(3) "The greatest movement of alkali salts is due to capillarity which operates through surface tension. When water moves by surface tension, the films around the soil grains move. As soon as the gravity water has drained away, the movements become entirely by surface tension. A loss of water due to evaporation changes the curvature of the water films and starts a capillary movement toward the point where the evaporation takes place. But when water moves by capillary action it is the water in the smaller spaces that moves, and not the water which is in the larger noncapillary spaces. Therefore the water which was drawn back into the capillary spaces and which carried some of the alkali salts as it flowed down into the soil starts upward and carries with it the salts in solution. The evaporation of an inch of water on the surface of the soil accumulates on the surface all alkali salts which were contained in that inch of water, while, on the other hand, the same volume of water leached down through the soil would probably not leach out an equal amount of the salts. From this it will be seen that the tendency of the alkali salts under irrigation is to move upward perhaps more rapidly than downward.

"From the above discussion it appears that surface tension or capillary attraction, as it is commonly called, is the most important agent in the movement of alkali salts toward the surface of the soil. Therefore, a soil which would permit the most rapid movements would be the most likely to accumulate alkali salts upon the surface. If two soils with different capillary powers were placed side by side, with the level of standing water the same, the soil which raised the water to the surface the more rapidly would the sooner accumulate an alkali crust."

THE POSITION OF MAXIMUM SOLUBLE SALT CONTAINED IN THE SOIL.

The following table summarizes certain observations which have been made concerning the depth at which soluble salts form accumulations.

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[1] Bul. No. 35, Bureau of Soils, p. 13.

Depth of accumulations of soluble salts in soils.

3-inch rainfall, Imperial Valley, Cal.	8-inch rainfall, Fresno district.	12-inch rainfall, Yellowstone Park.	15-inch rainfall, Ventura County, Cal.	20-inch rainfall, Grand Falls, N. Dak.
In virgin soils greater part of soluble salts at a depth of 18 inches.[1]	Sandy loams 3 to 4 feet; coarse sands 4 to 8 feet.[1]	Heavy soils 4 to 6 feet; sandy soils 7 to 11 feet.[2]	Bulk of soluble salts at 5 feet.[1]	Greater part of soluble salts below 3 feet.[1]

[1] Bul. No. 35, Bureau of Soils, p. 15.

[2] Bul. No. 14, Bureau of Soils, p. 27.

Two important actions take place in the movement of saline material in soils. Rainfall penetrates the surface soil and percolates down to certain depths. In its passage downward it dissolves a portion of whatever soluble salts may be present and thus leaches the material at the immediate surface. The extent to which this leaching would take place would be determined by the proportion of gravity water to water of capillarity and the penetration of the water. This is determined largely by the texture of the soil. With a porous soil this leaching action would be especially noticeable. In the leaching of a soil in the manner described above, it is evident that the more soluble constituents would be first dissolved and carried to the greatest depths. Underground water soon reaches a position of equilibrium which may be within the permanent ground-water level or within the zone close to the surface. Capillarity begins to act. The ground water moves toward the point at which evaporation takes place. It should be noted that when this water reaches its equilibrium position it has dissolved a large amount of salt. When the solution is returned by capillarity these salts are carried with it and deposited at the point where evaporation takes place. Capillarity may not return these salts to the surface, for evaporation may take place below the immediate surface, and the capillary water column may terminate at varying distances from the surface. The height to which the water is raised by capillarity would determine the position of accumulated salts. It has been shown in another place that where ground waters are deeper than 10 feet from the surface little or no evaporation from them takes place. This would indicate that ground waters at depths greater than 10 feet could not be concentrated by evaporation, and consequently there would be little or no opportunity for the separation of salines under such conditions.

NATURE OF SALINES IN SOILS.

Calcium, magnesium, sodium, and potassium are the bases almost invariably present. Sodium in almost every instance is the dominating base, while calcium and magnesium are usually the smallest in amount. Potassium is much less than sodium. In the Fallon soils sodium is 12.6 times potassium, while in the Utah soils it is 5.6 times. The acid radicals of chlorine, sulphur, carbon dioxide, nitrogen, and phosphorus are invariably present. Chlorides and sulphates usually predominate, although in some soils carbonates and bicarbonates are in greater abundance. The Fallon soils contain sulphates in greatest amount, while in the Utah soils chlorides are in greatest amount. Bicarbonates are usually present in greater amounts than carbonates. Phosphates and nitrates are present in most cases in traces, although in some exceptional cases nitrates may be present in appreciable amounts. Two Fallon soils showed over 2 per cent nitrate in the total solids. The basin soils would present many variations from the examples given. Borates, for instance, are common in many playas.

COLLECTION OF SALINES BY SURFACE WATERS.

RIVER AND LAKE WATERS.

Rivers being the main collecting agents for gathering salines from a given area and transferring them to the lakes and lake basins, the content and nature of the salines as well as the amount collected can be determined from the analyses of the river waters. It should be noted that the rivers receive a certain proportion of seepage water and consequently the chemical analysis reflects not only the nature of the salts collected from the weathering zone, but also the salts received from underground waters. It is to be regretted that analyses of composite samples taken from basin rivers over long intervals of time are not available. What analyses are given represent single samples. The results must be used with caution.

The lake waters represent the saline accumulations during present times. It should be noted that certain compounds are precipitating out continuously and consequently the composition of the waters represents an approach to equilibrium conditions for the particular time. Variation in climatic conditions results in the raising and lowering of lake levels. The fluctuation in lake levels, together with the continual accession of saline material, accounts for the variation in the analytical results often noted in the reports of analyses of lake waters of the basin. The fluctuations of lake levels would also produce a change in concentration and, consequently, the equilibrium conditions would be changed also. The more soluble salts are accumulating in these lakes while the more insoluble are precipitating out. The principal data concerning the chemical content of river and lake waters of the basin are given in Table XV (Appendix).

Much detailed chemical work has been done upon the California rivers by Van Winkle and Eaton,[1] and on account of the close proximity of this State to the basin region the results of their analyses are of importance. They are given in the table which follows:

Mean analyses, California rivers.

[Per cent of anhydrous residue.]

Constituent.	Humid (22 rivers); rainfall, 15+ inches.	Semiarid (16 rivers); rainfall, 15− inches.
	Per cent.	*Per cent.*
Cl	8.95	7.89
SO_4	14.91	37.02
CO_3	31.27	18.87
Na+K	12.53	12.34
Ca	15.52	12.83
Mg	5.37	5.76
Fe	0.12	0.02
SiO_2	11.33	5.27
	100.00	100.00
Solids on evaporation, parts per 100,000	16.5	62.7

From the study of the results the following conclusions are of importance to the present inquiry: The total soluble salts in a river water under normal conditions varies with the stream flow. They are a minimum for a maximum flow and a maximum for a minimum flow. Normal conditions may be assumed to be those for a humid region. The components of the total salts also follow the above rule. If we take the Yuba River as an example and apply this rule to the various soluble constituents, we find that chlorine, the sulphate radical, carbonic acid, sodium, and calcium follow this rule. Potassium fluctuates; magnesium shows little fluctuation; silica remains practically constant. In an arid or semiarid region soluble salts tend to accumulate during periods of low water. When the first floods come the river water gains in total solids and sometimes to a very marked extent, due to the washing out of these accumulated salts. Certain rivers, such as the Santa Ynez and the Owens River, maintain the amount of total salts at practically a constant figure. Concerning the comparison of the mineral content of waters in semiarid and humid regions Van Winkle and Eaton state:

First. "The average mineral content of waters in semiarid regions is, roughly, four times that of waters in humid regions.

Second. "Difference in percentage composition of the anhydrous residues shows that the waters in semiarid regions contain about two-thirds the proportionate amount of silica, less calcium; four-fifths as much carbonates, and twice as much sulphates as the waters of the humid regions. Their constituents are similar in amount. In regions of abundant rainfall disintegration of rock material can not keep pace with solution, erosion, and chemical decomposition. The more soluble constituents of the rocks are rapidly removed as they become exposed to the action of water, and their total amount in a given quantity of the solvent water is seldom great. In arid or semiarid regions, however, chemical action is frequently less marked than physical disintegration. The soluble materials of the disintegrated rock masses accumulate through periods of drought, allowing the water from subsequent rainfalls to take into solution a greater relative amount than is found in waters from more humid regions.

"In the waters studied the average amount of mineral in streams from the semiarid regions was 627 parts per million; in rivers of the humid regions it was 165 parts per million. The greatest average mineral content, 2,412 parts per million, occurred in Santa Maria River, which flows through a sandstone country receiving barely 10 inches of rain a year. The smallest amount of mineral matter was found in Merced River, 65 parts per million, or about one-fortieth of the amount for Santa Maria River.

"As the silica content is apparently unaffected by the amount of the other dissolved constituents, it may be expected that the percentage of silica in rivers of high dissolved solids will be correspondingly low. This is true in California waters, the average silica for the humid-region rivers being 13.4 per cent and for the semiarid-region waters 8 per cent of the total mineral matter in solution. The principal effect, then, of climatic condition on silica content is a negative one and it is apparently due merely to change in total mineral content.

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[1] Water-Supply Paper 237, U. S. Geol. Survey.

"By the decay of the abundant organic material in humid regions carbonic acid is set free, being dissolved in the surface waters or entering the air as carbonic dioxide. This carbonic acid, uniting with the carbonic acid of the alkaline-earth carbonates, produces the bicarbonates which are readily dissolved, so that surface waters in regions of abundant rainfall carry large amounts of the bicarbonate radical and of the alkaline earths. In regions of deficient rainfall, on the other hand, carbonic rocks are attacked to less extent and the gypsum and alkaline sulphates that are present are brought more largely into solution."

The conclusions of Van Winkle and Eaton may be applied to basin conditions. A somewhat different grouping of the basin rivers is desirable, and I have attempted this in the following. This grouping is not accurate, for the reason that some of the basin streams rise in the higher mountains and under conditions similar to many of the streams upon the western slope of the Sierras, while the lower courses of these streams are in the valleys and under semiarid or arid conditions. Three groups are made:

(1) Streams which have watersheds under humid conditions. These are Mill Creek, Leevining Creek, Rush Creek, the mountain streams tributary to Owens River, and the short streams of the higher ranges of the basin.

(2) Streams which have watersheds partly under humid conditions and partly under arid. These are the Truckee, Carson, Walker, streams tributary to Great Salt Lake, and streams tributary to the southern Oregon lakes.

(3) Streams which have watersheds under arid conditions. These are the Quinn, Armagosa, Humboldt, Reese, and Owens Rivers.

Streams of the first group are comparable to such rivers as the Yuba and the Tuolumne, and the California streams for humid conditions generally. Streams of the second group are comparable with the California streams under semiarid conditions. Streams of the third group are in a class by themselves, and, in the absence of detailed studies, can not be properly characterized.

The streams tributary to Great Salt Lake are characterized by high chlorine content, while the streams of the Lahontan Basin have a high sulphate content. Owens River is the only stream in which a noticeable amount of nitrates has been reported.

Lake waters are similar in composition to the river waters. There are some differences, and in order to show this I have worked out certain ratios which are given in the accompanying table.

Ratios between certain soluble constituents in lake and river waters.

Source of sample.	$\frac{\mathrm{Na}}{\mathrm{K}}$	$\frac{\mathrm{Ca}}{\mathrm{Mg}}$	$\frac{\mathrm{Cl}}{\mathrm{SO_4}}$	$\frac{\mathrm{H\,CO_3+CO_3}}{\mathrm{Cl+SO_4}}$
Rivers:				
Ogden	2.7	2.6	4.12	1.16
Weber	2.0	2.8	1.50	1.74
Bear	....	2.1	3.97	.53
Jordan	....	8.1	1.13	....
Humboldt	4.6	3.9	.15	2.45
Amargosa	11.9	....	.52	.30
Walker	....	6.0	1.11	1.28
Truckee	2.2	3.2	.58	1.63
Owens	....	3.5	.56	2.35
		2.6	.61	2.42
Lakes:				
Great Salt	6.6	.14	9.29	....
Winnemucca	18.9	1.10	12.73	.15
Pyramid	16.0	.10	7.81	.30
Humboldt	4.5	.70	9.73	.61
Walker	....	.56	1.11	.38
Mono	20.4	.40	1.81	.64
Owens	23.6	2.00	2.50	.70
Harney	18.6	....	3.50	.73
Abert	27.1	....	18.9	.54
Sevier	....	.04	4.8	....
CALIFORNIA RIVERS.				
Mean of rivers in semiarid region	....	2.51	0.21	0.83
Mean of rivers in humid region	....	2.88	.60	2.64

The sodium-potassium ratio has been discussed in another section. The calcium-magnesium ratio shows a marked decrease for the lake waters as compared with river waters. This can be explained by the fact that calcium readily precipitates as carbonate or sulphate, or may be removed by the agency of vegetable organisms[1]. The removal of calcium would leave the magnesium in greater relative amount. There is no doubt that magnesium is also precipitated as a carbonate, but is not eliminated at as great a rate as calcium. Chlorides are more abundant than sulphates in the lake waters as compared with river waters. This is undoubtedly due to the precipitation of the sulphate radical by lime. Carbonates and bicarbonates are in less relative proportion in lake waters than in river waters. This is accounted for by the precipitation of calcium and magnesium as insoluble carbonates.

Borates are conspicuous in Owens, Mono, and the lakes of southern Oregon. The waters of Owens Lake are noteworthy on account of the content of nitrates and arsenic compounds.

Certain regional characteristics become noticeable in a comparison of the chemical content of lake waters. The lakes of the Bonneville Basin are conspicuous for their lack of carbonates and bicarbonates and their high content of chlorides. Sulphates are present, but in moderate amount. The high content of these lakes in salines is to be noted also. The regional rocks of the Bonneville Basin are, for the greater part, sedimentaries. Limestones are common.

The lakes of the Lahontan Basin have a much lower saline content, and contain chlorides, sulphates, and carbonates. Chlorides usually dominate, but in Pyramid, Winnemucca, and Humboldt Lakes carbonates are somewhat greater in amount than chlorides. The regional rocks are characterized by a greater area of igneous rocks than the Bonneville Basin.

Owens and Mono Lakes contain chlorides and carbonates in greatest amount. Chlorides are greater in amount than carbonates and sulphates are least. These lakes are characterized by a high saline content. The regional rocks are predominatingly igneous. The southern Oregon lakes are low in sulphates and have about equal amounts of chlorides and carbonates. In the case of only one lake are the chlorides exceeded by the sulphates. The regional rocks are igneous.

ANNUAL SALINE CONTENT OF RIVER DISCHARGES.

The rate at which salines are accumulating at present in the basin lakes can be calculated approximately from the mean annual flow of the principal rivers and their saline content. As has been mentioned before, the chemical data are insufficient, and, consequently, the conclusions give only approximate results. It is believed that the figures are conservative and rather under than overestimates. In Table XVI (Appendix) are given the tons of salines discharged by the Owens, Humboldt, Truckee, Walker, and Bear Rivers. The total salines discharged by these five rivers into their lake basins is 1,692,153 tons per annum.

An approximate determination has been made for four basins and is given in the accompanying table:

Discharge of salines into four important lake basins.

Basin.	Total run-off per annum for basin.	Rivers typical of run-off water.	Mean annual flow of these rivers.	Ratio of total run-off to flow of rivers.	Salines discharged per annum by rivers.	Total salines discharged per annum into basin.
	Sec.-feet.		*Sec.-feet.*		*Tons.*	*Tons.*
Bonneville	3,583	Bear	1,860	1.9	1,259,235	2,392,546
Lahontan	2,406	Walker, Humbolt, and Truckee	1,504	1.6	286,019	457,630
Owens	306	Owens	306	1.0	102,228	102,228
Southern Oregon lakes	724	Truckee	1,030	.7	155,335	108,734

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[1] Bul. No. 108, U. S. Geol. Survey, p. 94.

The total salines collected by the rivers of these four basins approximate 3,061,138 tons per annum. The contribution per square mile is given in the following table:

Quantity of salines collected by rivers tributary to four important lake basins.

Basin.	Area.	Quantity per square mile.
	Sq. miles.	*Pounds.*
Bonneville	49,500	96,600
Lahontan	40,000	22,880
Owens	3,200	63,800
Southern Oregon lakes	[1] 2,000	108,720
Average for four basins		64,800

[1] Estimated.

These figures represent the most active basins, excepting the one in which Mono Lake is situated. They may be taken as representing the northern and western parts of the Great Basin. The southern half of the basin must contribute a very much smaller amount of saline material to the sinks.

While the above figures appear large and may be large, still when compared with estimates from humid regions they do not appear unreasonable. Van Hise quotes the estimate of T. Mellard Reade[1] for the amount of salts per square mile per annum for the whole globe as follows:

Total, 192,000 pounds. Of this total, calcium carbonate is 10,000 pounds; calcium sulphate, 40,000; sodium chloride, 16,000; silica, 14,000; magnesium carbonate, 8,000; iron oxide, 2,000. Clarke[2] quotes the figures of Dole and Stabler[2] for chemical denudation in the United States as 87 tons per annum per square mile. This would be 174,000 pounds and would apply to humid conditions. The figures given show that the chemical denudation in the more active parts of the basin region is equivalent to 37 per cent of this figure.

Table XVII (Appendix) gives the salines in pounds for each square mile of watershed for the Truckee, Walker, Humboldt, and Owens Rivers. For purposes of comparison I have added the figures for five rivers in California. The figures show the close relation between run-off and salines removed per square mile. While the saline content of the waters of a river in the semiarid region may be much higher than for a river under humid conditions, the total salines collected in a given time from a unit area is usually much less. This is easily explained by the fact that the greater proportion of the surface waters is absorbed by alluvial material and their salts are retained. The low yield of the Humboldt River is noteworthy. The very small run-off is sufficient explanation. In general, the figures presented show that the greater the run-off the greater the "crop" of salines from a unit area. Exception of the Kern River and the San Ysabel Creek may be made. The character of the watershed and the rate of decomposition of the regional rocks enter as a factor. The greater relative "crop" of these two streams is undoubtedly due to a greater rate of decomposition of the rocks, or a greater amount of salines in the disintegrated rock upon their watersheds. The water-duty factor, pounds of salines per square mile per second-foot per annum, gives a better basis of comparison between rivers under arid and rivers under humid conditions. Omitting the Kern and San Ysabel, since these streams have exceptional conditions upon their watersheds, the streams of the basin region show a much higher duty than those of the humid region in the near neighborhood. To put it in another way, the same quantity of water on the Owens River watershed would gather 4.5 times as much saline material as upon the Tuolumne, and 3.2 times as much as upon the Truckee.

The figures given can not be taken as the annual rate of chemical denudation for the basin, for it must be kept in mind that the basin streams gather only a part of the run-off waters, the remainder being absorbed in the sinks and basins. Expressed as an equation—Pounds of salines liberated per square mile=pounds of salines retained in soil and sinks+pounds gathered by rivers and discharged into lakes. No data upon the amount of salts absorbed are available and, consequently, the second number of this equation can not be quantitatively stated. The third number of the equation is the only one which admits of approximate quantitative statement, and figures for this have already been given.[1]

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[1] Treatise on Metamorphism, p. 486.
[2] Bul. No. 491, U. S. Geol. Survey, p. 103.

Of the ions, sodium and potassium are of most interest. These constitute 19.4 per cent of the saline material. Potassium may be taken as 20 per cent of the combined weight of sodium and potassium. Applying these proportions to the 3,061,138 tons of salines for the four basins gives 593,860 tons of sodium and potassium, and 118,772 tons of potassium as the annual "crop" for approximately 95,000 square miles of the basin.

The figures given in the preceding represent the rate of accumulation under present conditions. The humid conditions of the Quaternary must have produced a much greater rate of accumulation than at present. The greater area of lake surface during Quarternary times would give less land surface for chemical denudation. For the Lahontan and Bonneville Basins it has been shown that for one unit of lake area there were 3.5 units of basin area. For the 95,000 square miles under consideration this ratio would give 74,027 square miles of land and 20,973 square miles of lake surface. If we assume that the rate of accumulation equaled the present rate for the Tuolumne River watershed, the above area of land surface would yield a "crop" of 13,650,000 tons per annum, or about four times the present rate of accumulation. While these results are no doubt crude, they at least give us some idea of the enormous amounts of salines that must have been discharged by the rivers of Quaternary times into the Quaternary lakes.

SALINE DEPOSITS.

To avoid repetition, this subject is presented under the following heads: Nitrates; Borates; Alum; Alunite; Crusts and Efflorescences; Playa Deposits; Deposits Resulting from Desiccation of Lakes; Buried Deposits of Salines; Salines in Present Lakes; Calcareous Deposits about the Shores of Present Lakes; Potash-rich Minerals; and Gypsum.

NITRATES.

Gale[2] has summarized the occurrence of nitrates in the Great Basin region. From his work I give below some of the principal facts.

Nitrates have been reported in Utah, in the vicinity of Marysvale, Monroe, and Greenwich Canyon, and Grass Valley; in Nevada, in the vicinity of Lovelock, in northwestern Washoe County near Leadville, and in the canyons bordering the west side of Railroad Valley; in California, in the vicinity of the Calico Mountains, in the region northeast of Salton, along the Amargosa River near Tecopa, and in the vicinity of Death Valley, Searles Lake, and Danby Lake. The compounds reported are potassium, sodium, magnesium, and calcium nitrates. Potassium nitrate is the compound most often found. The deposits are of three types—cave, playa, and as efflorescences. Most of the Nevada deposits are of the cave type. They occur as veins, stalactites, and crusts in deposits protected from the action of surface waters. In playas, the nitrates are mixed with other salines. Occasional efflorescences of nitrates are found. The deposit occurring south of Tecopa, Cal., and along the Amargosa is of this type. The nitrates of the basin region are either leached from the soils or originate from the decaying organic matter accumulating in the caves. Gale is of the opinion that probably a majority of the nitrate deposits result from the decomposition of bat or similar guano in caves, or crevices in the rocks.

Nitrates have been reported in small amounts in river and lake waters. Van Winkle and Eaton report the nitrate radical in 18 river waters out of some 30 examined in California. The average content for the Owens River is 1.7 parts per million. This is equivalent to 0.5 per cent of the anhydrous residue. A more extended search for this radical would, no doubt, show it present in small amounts in most of the river waters of the basin. The origin of nitrate in river water is due to the leaching action of rain water on soils. Owens Lake contains 948 parts per million of nitrate radical.[3] J. G. Smith reports traces of nitrates in all the waters from the southern Oregon lakes which he examined. I have no doubt that this radical, in small amounts, could be found in other basin lakes. In the analysis of the soluble material of basin soils

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[1] The mean annual run-off for the basin region was approximately determined to be 1.06 inches of rainfall If we assume the saline content to be 62.7 parts per 100,000 (the mean saline content of California rivers for semiarid conditions), the saline content in the run-off from 1 square mile is 96,251 pounds. This approximates the figure obtained for the Bonneville basin. On this basis the annual crop of salines for the whole basin would be 10,105,200 tons. The playa, silt and lake area is about 30 per cent of the basin area or 63,000 square miles. The concentration of the annual crop of salines on this area would give 164 tons per square mile or a surface crust 0.0012 of an inch thick.

[2] Bul. No. 523, U. S. Geol. Survey.

[3] Water-Supply Paper No. 237, p. 122.

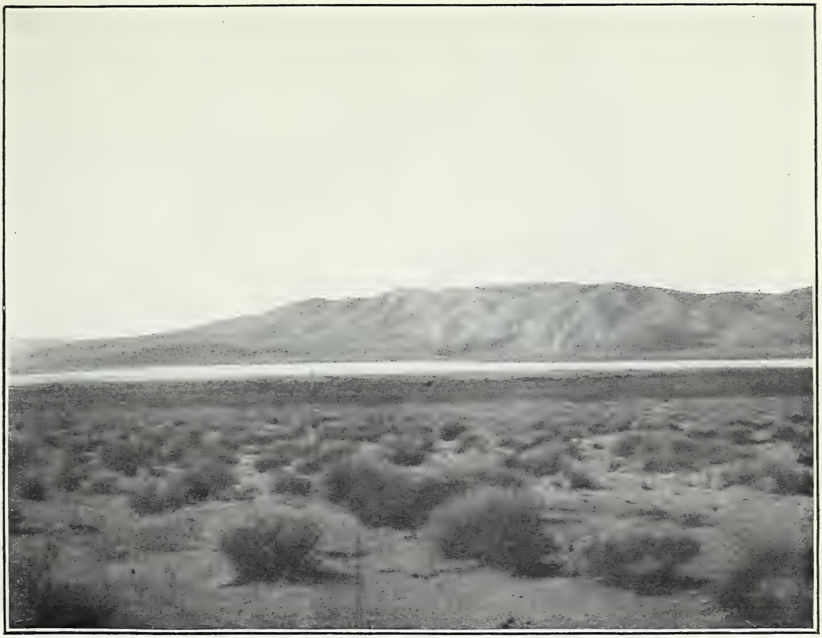

FIG. 1.—TEELS MARSH, NEV. VIEW LOOKING SOUTHWEST. TYPICAL SMALL BASIN.

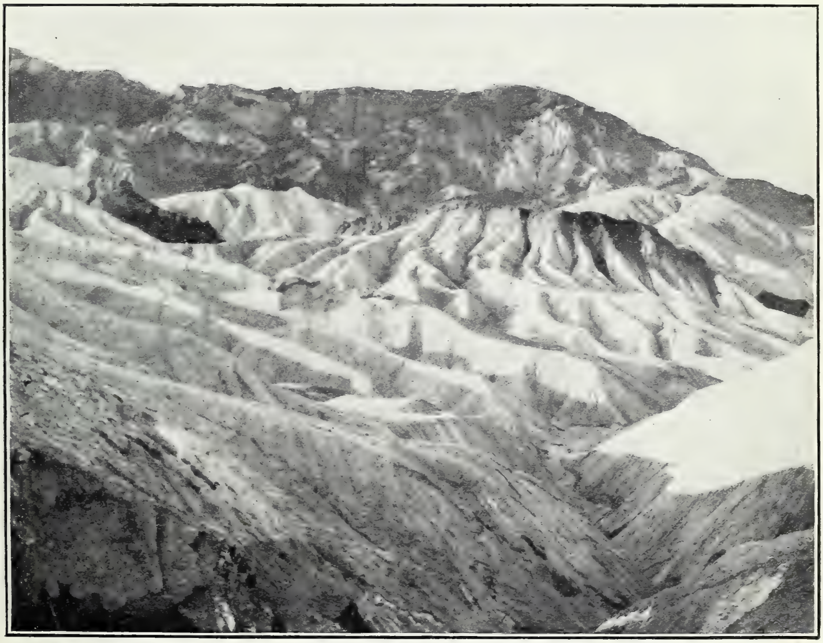

FIG. 2.—DEATH VALLEY, CAL. EROSION OF TERTIARY BEDS SOUTH OF FURNACE CREEK AND EAST OF THE VALLEY. BLACK MOUNTAINS.

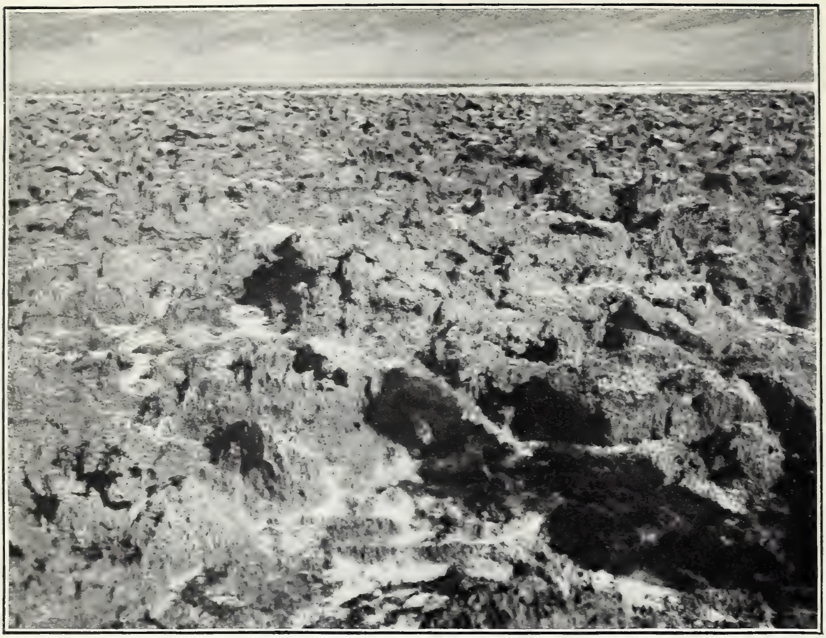

FIG. 1.—ROUGH SALT AREA, DEATH VALLEY—EAST SIDE; EAST OF BENNETTS WELLS.

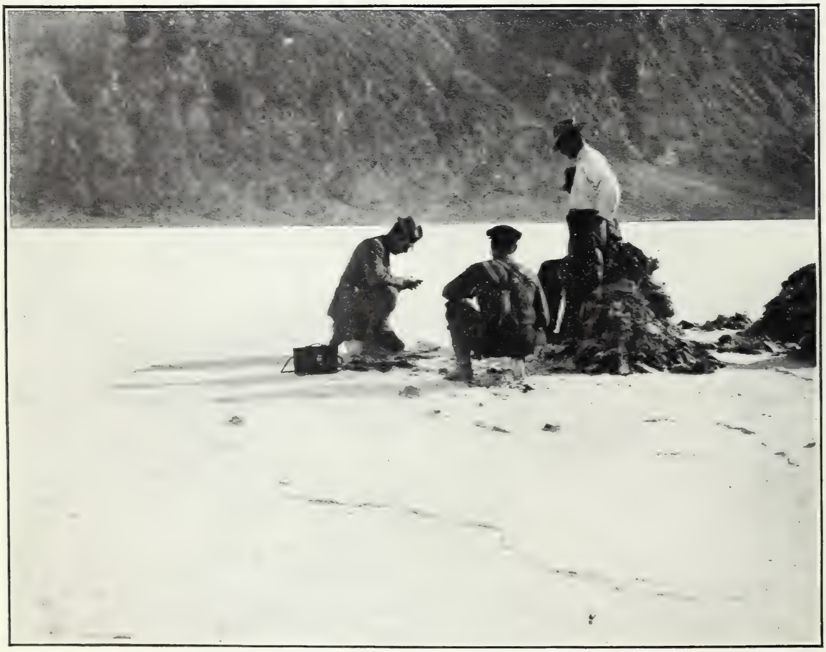

FIG. 2.—SMOOTH SALT AREA, DEATH VALLEY—EAST SIDE; EAST OF BENNETTS WELLS.

nitrate from traces to appreciable amounts has been shown. No deposits of economic importance have as yet been discovered in the basin region and the outlook for any important discovery in the future is not promising.

BORATES.

Borates occur in many localities in the basin region; in fact, they may be said to be found in the western half of the basin region from Oregon to the Mojave Desert. There is a conspicuous lack of borates in the eastern half of the basin, although traces of boric acid have been reported in the analyses of the waters of Great Salt Lake.[1] While the borate radical has not been reported in river waters, there is no doubt that it exists in most of the basin streams in minute quantities. The borate radical has been reported in Harney, Mono, Large Soda, Summer, Fossil, Christmas, North Alkali, Middle Alkali, South Alkali, and Abert Lakes. In most of these lakes it is present in very small amounts, but in Mono, Owens, and Large Soda Lakes it is present in quantities ranging from 16.37 in Mono to 29.91 parts per hundred thousand in Owens Lake. It has been reported in the waters of hot springs. The water of Steamboat Springs, Nev., contains 21.7 parts per hundred thousand boric anhydride. A more detailed examination of the waters of hot springs in the basin region would undoubtedly show many other examples of the presence of borate minerals. Borates are discharged into lakes by river and seepage waters.

The workable deposits of borax are of two types—the marsh, playa, or dry-lake type, and the bedded deposits. The former occur in Rhodes, Teels, and Columbus Marshes, Nev.; in basins along the Amargosa River, in Death Valley, Saline Valley, and Searles Lake, Cal.; at Sand Springs and Fish Lake Valley, Nev.; and in the district immediately south of Alvord Lake, Harney County, Oreg. The latter occurs at Furnace Creek, Ryan, and at Borate, in the vicinity of Dagget, Cal. The bedded deposits are found in Tertiary lake beds.

The playa deposits have many features in common. They occur usually as peripheral deposits about the sink of an inclosed basin. They are formed by the action of drainage waters dissolving the borate minerals from the alluvial material surrounding the sink. Where the drainage water strikes the more or less impervious silts of the central part of the basin, it is deflected toward the surface and if it accumulates sufficiently to reach the zone of surface capillarity it is drawn to the surface and by evaporation leaves the soluble salts as surface incrustations and efflorescences. These salts accumulate and in time form workable deposits. The crusts are scraped up and hauled to treatment plants in which the crude borax is separated from mechanical impurities and associated salts. The deposits are slowly renewed. This fact is well illustrated by a series of analyses of crusts taken from Searles Marsh and given in the following table:

Analyses of renewed efflorescences of borax at Searles Lake.[1]

Constituents.	6 months.	2 years.	3 years.	4 years.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Sand	58.0	55.4	52.4	53.3
$NaCO_3$	5.2	5.0	8.1	8.0
Na_2SO_4	11.7	6.7	16.6	16.0
NaCl	10.9	10.0	11.1	11.8
Borax	14.2	12.9	11.8	10.9

[1] 10th Annual Report, Cal. State Mineralogist. Analyses by C. W. Hake.

Deposits of this character derive their borate minerals from alluvial material. The disintegration and erosion of the Tertiary lake beds account for a part, at least, of the borate in the alluvial material of a number of the deposits mentioned above. The general prevalence of volcanic rocks and evidences of late volcanic activity may well account for the remainder.

Recent deposits of borax at depth are shown by the borings in Searles Marsh. The borate minerals are associated with other salines. They have been found not only in the marginal portions of the sink, but also in the central part. C. E. Dolbear[2] presents analyses of the material taken from two borings—the first, within the central area of the sink; the second, on the outside margin. In the first boring borax is shown in percentages ranging from 1 to 5.5, and at depths extending from 18 to 50 feet. Below this depth traces of borax occur, while in the material extending from the surface to 18 feet practically no borax, or only a trace, was found. In the second, borax was reported in percentages ranging from 5.56 to 6.57 and extending from a depth of 30 to 45 feet. Above and below these depths only traces of borax were reported. The results of these borings would indicate that in some of the playas, at least, might be expected concentration of borax minerals at depth.

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[1] Bul. No. 491, U. S. Geol. Survey, p. 144.
[2] Eng. and Min. Jour., Feb. 1, 1913, p. 260.

The minerals reported from deposits of the playa type are borax (sodium borate), ulexite (sodium calcium borate), and colemanite (calcium borate). The content of the crude material ranges from 5 to 20 per cent boric acid. Deposits of this type are no longer of economic importance.

Deposits of the second type are the important sources of borate minerals. In the basin region they are worked at Ryan and in the vicinity of Furnace Creek (Mount Blanco). For a description of these deposits the reader is referred to Campbell[1] and to Keyes.[2]

These deposits are of importance in that they account for the source of a part, and perhaps the principal part, of the borate material in certain playa deposits, notably those in Death Valley and along the Amargosa River. Of the bedded deposits Keyes describes two general types. The one is illustrated by the mines northwest of Dagget, Cal. In this locality the borate minerals are found in a finely divided state in beds of blue clay. The workable beds contain from 10 to 12 per cent boric acid. The other type is characterized by nodules and masses of almost pure colemanite in clays and shales of Tertiary age. Respecting the origin of these deposits, Charles Laurence Baker,[3] after discussing the possible formation of the deposits by the evaporation of a body of water of considerable depth, presents the following:

"The alternative hypothesis that these minerals had their immediate origin in hot springs and solfataras opening directly into shallow lakes, perhaps only of seasonal duration, or in playas, has much to commend it, especially when considered in connection with the numerous evidences of shallow water deposition. These evidences comprise ripple marks, sun cracks, and rain prints, which are found on the finer as well as the coarser beds, and the layers of finer breccia and conglomerates interbedded with the fine shales and tuffs. Shallow lakes or ponds probably existed at times during the deposition of the fossiliferous tuff member, for they seem to be necessary to account for the presence of the gasteropods. The paucity or absence of fossils in the borate and the fine ashy and shaly tuff members, as well as the presence of the colemanite, limestone, and gypsum layers, apparently indicates the salinity of the waters.

"There was great volcanic activity before and during the deposition of the Rosamond. The larger fragments of lava were most probably derived from flows subject to erosion somewhere in the area tributary to the basin of deposition. Interbedded flows of both acidic and basic lavas make up a part of the Rosamond. But the fine volcanic ash was probably blown in by the wind or settled during explosive volcanic outbursts and need not have come from the immediate vicinity. The common view of the origin of calcium borate from solfataras and hot springs associated with the abundant contemporaneous vulcanism is likely to prove to be the correct explanation for the borax beds in this region."

I am in accord with the main points in Baker's view. It must be noted, however, that in the colemanite deposits of the type exemplified by Mount Blanco a considerable amount of secondary action is noticeable. There are many distinct veins of colemanite associated with the layer beds. One gets the impression that these are anything but bedded deposits. I am inclined to the view that the Mount Blanco deposits represent the solution of the borate minerals from beds and their concentration in more or less open fissures in close proximity as veins.

ALUM.

Spurr[4] reports a deposit of alum and sulphur 10 miles north of Silver Peak, Nev. The area in which this mineral occurs is about 200 feet in diameter. The alum is associated with sulphur in rhyolite. It forms a network of small veins in the broken rhyolite. The rhyolite is intrusive in Tertiary sedimentaries. The mineral is a pure potash alum, kalinite. Spurr considers that the alum results from the action of steam and sulphuric acid emitted from solfataras. The acid attacks the potash and alumina of the rhyolite and forms kalinite.

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[1] Bul. No. 200, U. S. Geol. Survey.

[2] Borax deposits of the U. S., Trans. Am. Inst. Min. Eng., vol. 40, p. 674.

[3] Bulletin of the Dept. of Geology, Univ. of Cal., **6**, p. 358.

[4] Professional Paper No. 55, U. S. Geol. Survey, p. 157.

G. I. Adams[1] describes a similar deposit at the Rabbit Hole Sulphur Mines, Nevada. Instead of kalinite, alunite is the mineral formed in association with sulphur. Solfataric action is considered the cause of the formation.

Several samples were submitted to the cooperative laboratory from what was called a hot-spring deposit occurring 30 miles northeast of Wells, Nev., in Thousand Springs Valley. The mineral contained crystals of kalinite, sulphur, and gypsum. The two samples showed the following analyses:

Number.	K_2SO_4, $Al_2(SO_4)_3$.	Ca SO_4.	$Fe_2(SO_4)_3$.	S.	Na_2SO_4.	NaCl.	Insol.	H_2O.
319-1	40.06	18.20	Tr.	Present.	Tr.	Tr.	8.94	33.50
319-2	2.35	15.74	Tr.	Present.	Tr.	Tr.	75.28	5.10

The determination was made upon the water-soluble material in both samples. A test for alunite gave negative results. The richer material contains 57.14 per cent kalinite. The sample of water from the hot springs in the near vicinity gave the following results:

Analysis of water from hot spring.

	Per cent.		Per cent
Ca	11.1	SO_4	8.2
Mg	Trace.	HCO_3	52.2
K	5.1	Total solids on evaporation (parts per 100,000)	62.0
Na	2.2		
Cl			

The evaporation of a water of this composition would account for the potassium and alum in the surface deposit of the spring.

Undoubtedly there are other occurrences of alum. No attempt has been made to exploit deposits of this nature. Systematic sampling to determine the average alum content and the total tonnage available has not been made in any one case and, consequently, the value of such deposits is an open question.

ALUNITE.

Gale has described the occurrence of alunite in the Great Basin, and for a detailed presentation the reader is referred to his bulletin.[2] This mineral has been reported from the following localities:

Goldfield, Nev.; associated in soft, massive form in ores, and occurs also as a constituent of altered volcanic rocks. Kalinite is conspicuously associated with it.[3]

Cactus Range, south of the Goldfield-Cactus Road; associated with silicified rhyolite.[4]

Cuprite, 12 miles south of Goldfield; associated with an altered rhyolite pumice.[5]

Rabbit Hole Sulphur Mines, 35 miles northwest of Humboldt House, Nev.; associated with sulphur in Tertiary sedimentaries. The rocks are much silicified in the neighborhood of the sulphur deposits.[6]

Camp Alunite, 22 miles southeast of Las Vegas, Nev.; associated with altered andesites and monzonites.[7]

Las Vegas, locality 15 miles south of Las Vegas, Nev.; sample of alunite submitted by J. A. Delameter, who reports no name for the district, and states that there is apparently a considerable quantity of the mineral. The mineral submitted is massive alunite and contains 8.98 per cent potash.[8]

Marysvale, Utah, Little Cottonwood Canyon, 7 miles southwest of Marysvale. The alunite occurs in veins. The main vein has been traced for a distance of 3,000 to 3,500 feet, and reaches a thickness of 20 feet in the widest portion. The potash content is from 10 to 12 per cent. A parallel vein 6 feet wide occurs close to the main vein.

A review of the conclusions of Ransome, Butler, Adams, and Hill concerning the genesis of this mineral has resulted in the following summation: The occurrences of alunite may be grouped in two general types—those in which alunite was formed from the action of solfataric waters or vapors carrying sulphuric acid upon igneous rocks rich in potash, and those in which solutions rich in sulphates and coming from deep-seated sources rose through fissures and deposited their mineral content where temperature and pressure conditions favored deposition. In the first type the alunite has been deposited more or less *in situ*. In the second, the alunite originated at depth and was deposited close to the surface. Deposits of the first class are disseminated, while in the case of the second type the deposits are concentrated. To the first type belong the Goldfield, Camp Alunite, Rabbit Hole Spring, Cactus Range, and Cuprite occurrences. To the second belong the Marysvale occurrences. Alunite is a possible source of potash.[1] Of the known occurrences of this mineral in the basin region, the Marysvale deposit is the only one which shows possibilities of commercial exploitation. The results of work upon this deposit will be looked forward to with interest. In view of the widespread solfataric action, in past as well as present geologic periods, it is not improbable that other deposits of alunite will be discovered in this region.

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[1] Bul. No. 225, U. S. Geol. Survey, p. 497.

[2] Bul. No. 511, U. S. Geol. Survey.

[3] Professional Paper No. 66, U. S. Geol. Survey, p. 108, Ransome.

[4] Bul. No. 308, U. S. Geol. Survey, p. 48, Ball.

[5] Professional Paper No. 66, U. S. Geol. Survey, Ransome.

[6] Bul. No. 225, U. S. Geol. Survey, Contributions to Economic Geology, p. 500.

[7] Eng. and Mng. Jour., Dec. 19, 1908, p. 1203.

[8] Records of the Cooperative Laboratory, Reno, Nev.

ALKALI CRUSTS AND EFFLORESCENCES.

It is difficult to draw a sharp line between deposits of this type, playa deposits, and deposits resulting from the desiccation of lakes. I have included under this head, however, all surface deposits which have originated during present times and which are of inconsequential thickness. These deposits have their origin in the evaporation of shallow bodies of rain water, or in the action of seepage waters in bringing dissolved salts to the surface, either by springs or capillarity. Hot springs are also responsible for crusts in their immediate vicinity.

These occurrences are usually characteristic of the playas or sinks. In Table XVIII (Appendix) are presented analyses of crusts taken from a number of localities. The average of these analyses shows the ions in the following order: Na, 30.23; Ca, 2.29; K, 1.68; Mg, 1.38; and the acid radicals SO_4, 30.39; Cl, 21.64; HCO_3, 6.22; CO_3, 6.13. The average analysis shows the predominance of sodium. The ratio of sodium to potassium is 19.1 to 1. The sulphate radical is in excess of the chlorine. Carbonates and bicarbonates are usually present and in a few cases are in large excess of chlorides and sulphates. Sodium chloride and sulphate are the two compounds most abundant. Potassium is usually small in amount, although in a few of the Utah crusts this element is present in percentages ranging from 3 to 6.

In Table XIX (Appendix) are given a number of analyses of salt crusts and waters from Railroad Valley, Nev. The samples were taken by E. E. Free and J. Hance. They were analyzed by A. R. Merz for the percentages of soluble salts and the potash content of the soluble salts. The samples represent a general survey of this area. They show, on the whole, a high content of potash. Six crusts and one brine were analyzed by J. A. Cullen, and his results are given in Table XX (Appendix). They show that sodium chloride is the compound most abundant, with potassium chloride usually next, followed in order of abundance by sodium sulphate, sodium bicarbonate, sodium carbonate. The average ratio of sodium to potassium is 5.7 to 1. The presence of potassium compounds in these crusts first attracted attention to this area and led to the exploratory work done by the Railroad Valley Saline Co.

The origin of salines of this nature is simple. They may be said to be derived from the weathering of rocks and the liberation of contained salines in the drainage area of the tributary basin. Through the agency of surface and underground waters they are collected in low places.

Such deposits, excepting the borates, which have been discussed previously, have no commercial value. The complex mixture of salts and the superficial nature of the deposits are the reasons for nonexploitation. In a few local cases salt has been gathered from crusts of this nature and marketed. No serious proposal has been made, as far as I am aware, for the exploitation of alkaline crusts rich in potash, although the aggregate amount of potash in an area like that of Railroad Valley must be very large. The chief interest in these deposits lies in the insight which they give into the chemical nature of the salines at present accumulating in the arid basins of the Great Basin.

PLAYA DEPOSITS.

Perhaps one of the most common topographical features is the desert basin. The basin may be circular, elliptical, or greatly elongated on one axis, forming a long, narrow valley. Such basins usually have in their lowest part a level area devoid of vegetation, sometimes covered with saline crusts, but more often simply consisting of a rain-puddled sheet of clay. To this central portion the term "sink" or "playa" is applied. The sink serves as a reservoir for the basin which it occupies. Naturally, it also serves to receive whatever soluble material is brought to it by surface or underground waters. As a consequence, playas may be looked upon as favorable places for the accumulation of salines. In order to present more clearly the nature of playa deposits, I have sketched the structural development of a desert basin.

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[1] For the conditions under which potash is made available in alunite see Cir. No. 70, Alunite as a source of Potash, Bureau of Soils, U. S. Dept. of Agr. For use of alunite as a fertilizer see Cir. No. 76, Alunite and Kelp as Potash Fertilizers, Bureau of Soils, U. S. Dept. of Agr.

STRUCTURAL DEVELOPMENT OF A DESERT BASIN.

The adjustment of the fault blocks of the Great Basin initiated a period of erosion, with its consequent deposition of detrital material in the intermountain areas. Flanking the mountains first appeared steep sloping aprons, or talus slopes. The finer sands and gravels were deposited in a wider zone at the foot of the apron area, and in the central portions the finest silts and clays were deposited. During this period shallow lakes no doubt occupied many of the basins. As erosion proceeded finer material was brought down and the mountain aprons assumed a less taluslike appearance. The sand and gravel aprons extended out and encroached upon the silt area and sufficient silt was brought down to fill the central basin and in some cases to obliterate the shallow lakes occupying them. Were lateral streams the only agents of transport, we should have a very definite structure revealed by the basin. A cross section of such an ideal basin would show a wide, level, and relatively thin body of fine silts and clays, flanked on either side with masses of detrital material rising in long, sweeping grades to the steeper slopes of the mountains. A gradation from fine sands to coarse angular débris mixed with material of all sizes would be noticed in passing from the central portions of the playa to the steeper mountain slopes. Figure 3 illustrates the section described. Under the conditions indicated above we should expect the central mass A to be characterized by little movement of ground water, while the flanking masses B and B would be zones in which ground waters could actively circulate. With the progress of time, we should expect the apron slopes to flatten and the silt and clay area to extend laterally until a shallow, panlike basin would result. Surface waters would accumulate and shallow lakes would form in the rainy season. The impervious bottom of this lake would protect the waters from loss by seepage. The evaporation of these lakes would leave surface accumulations of salts which would receive fresh accessions each year until deposits of appreciable thickness would make their appearance.

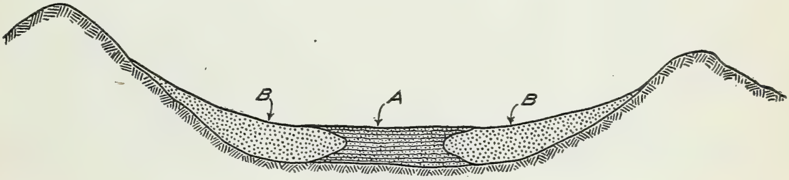

FIG. 3.—Ideal cross section of a desert basin.

Water is not the only agent which acts. Wind erosion and deposition also plays an important part. Under the influence of this agent the central portion A of the basin would not be composed of a homogeneous mass of clay and silts, but we should expect to find its homogeneity disturbed by layers of sand, volcanic ash, or other wind-blown material. Such beds would be continuous in a large measure over basin areas occupied by shallow lakes, but in the case of the ordinary playas conditions would not be favorable for the deposition of wind-blown material in thin beds. Upon the dry playas we should expect to find the fine silts of the central portion more or less eroded by the wind and deposited over the outwash slopes, or in certain portions of the basin as dunes. It is not an uncommon thing to find in a playa area one or more portions occupied by sand dunes of considerable extent. Another point should be mentioned, and that is that in periods of excessive rainfall or during cloud-bursts the streams would be so increased in volume as to carry out upon the central silt area sand and gravel. In this way tongues of coarse material would be formed in the silt portions and would form beds in which ground water could circulate. A perennial stream entering one end of a basin would effect a somewhat similar structure, but on a much greater scale.

The width of the intermountain spaces and the height of the inclosing mountain ranges would determine the proportion between the silt and detrital masses. With narrow valleys and high mountain ranges we should expect the outwash slopes to meet or even overlap at the center. As the valley filled a mass of silt of triangular section would be formed in the central part. Figure 4 illustrates this structure.

Some basins are characterized by having the silt area on one side of the intermountain space. This is caused by a difference in elevation of the mountain ranges and a difference in climatic conditions. The higher mountain ranges command a greater rainfall. We would therefore expect that greater erosion would result from the higher mountains than from the lower. This would result in apron slopes of greater extent from the sides of the higher mountains than from the lower. This would place the silt area close to the lower mountain range. Figure 5 illustrates the structure.

The ground-water conditions in basins of the types illustrated are worthy of further comment. In the case of figure 3, and assuming a region of inconsiderable rainfall, we should expect that the ground-water accumulations in B portions would be smaller and found at relatively great depths. The silt mass would retain its moisture close to the surface and lose it by evaporation. Capillarity would draw up the moisture together with any soluble salts for a depth of 10 or possibly more feet from the surface. At the central mass, built up by silt, or wind deposition, we would expect the soluble salts to be drawn upward and to remain as a conspicuous surface feature. Only on the edges of the silt portions would we expect to find any buried salt crusts and these would be distributed irregularly and be comparatively thin. In the case of a moderate rainfall we should expect an accumulation of ground water in B portions and the level of this ground water would reach the surface on the periphery of the silt mass. It would appear as spring water in the coarser material and as seepage water in the finer and more compact marginal portions. Under conditions of this kind we should expect the marginal portions of the silt mass, if not the entire silt mass, to be saturated with moisture. If the amount of this water, plus the rainfall on the playa area, would be sufficient to replace the evaporation losses, a lake might be expected to form and to remain as a more or less permanent feature. If insufficient, we should expect a lake to form during part of the year, and in the summer months the standing water would evaporate, leaving a mud flat. Another case might be mentioned, and that is where the ground water plus the rainfall would be insufficient to form standing water and only just sufficient to maintain a mud flat during a part of the year.

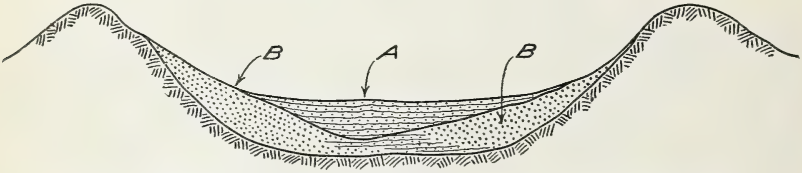

FIG. 4.—Cross section of a basin occupying a narrow valley between high mountains.

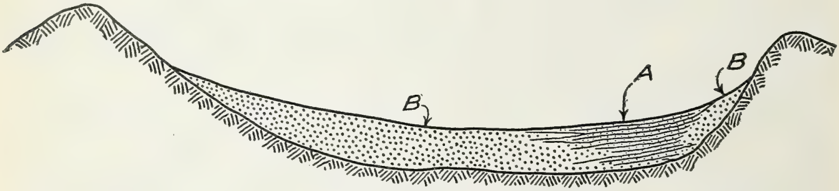

FIG. 5.—Cross section of a basin having higher mountains on one side than on the side opposite.

In the case of figure 4 ground water would be present beneath the entire basin and this would be in some cases artesian water. If the silt portion A maintained its homogeneity ground-water accessions could come only from the marginal portions of the playa area. That this is not an ideal condition may be concluded from the fact that a spring, or springs, is not infrequently found in the central portion of the playa. In some cases this spring is sufficient to supply a small pond and in others the water flows out and evaporates. An excellent example of this kind is found in Rhodes Marsh. In almost the center a spring makes its appearance and a flow of some magnitude runs out and meanders on the flat to be lost by seepage and evaporation. During some years the rainfall plus this flow is sufficient to form a shallow lake.

A conspicuous feature of many of the playas is the marginal rim of mud about the relatively dry central portion. Silver Peak, Rhodes, Death Valley, and Teels Marsh are examples.

Another condition merits mention here. Often a playa will be in the focus of some dominant surface drainage or ground-water drainage. These combined are sufficient to feed a stream for a portion of the year and the basin receives sufficient water to form a permanent lake. The lakes occupying the Quaternary basins are of this character.

Respecting the movement of salines in solution, it will not be out of place to mention the following: Assuming the ideal basin, and considering such a basin supplied by rainfall and not receiving the discharge of any stream, the run-off ground water reaches the central playa and brings with it more or less soluble salts. The ground water which seeps in from the margins brings in considerable salts. This is shown by the crusts and efflorescences which are continually forming on the marginal portions. The water which comes from springs in the central part of the playa is comparatively free from salts. We would expect that the deeper water would be comparatively free from salines and only in the case where it flowed up through saline beds would we expect to find much evidence of soluble salts. A not unimportant conclusion may be drawn here and that is that artesian flows in the central portion of a playa, if free from more than nominal amounts of soluble salts, indicate the absence of deposits of salt at depth.

PLAYAS.

Desert basins not occupied by perennial lakes may be divided into two groups—mud playas and marshes. The former are playas which are dry and without any great accumulation of underground waters; the marshes are playas noteworthy on account of the accumulation of considerable bodies of underground water and in which the water can be found comparatively close to the surface. For convenience in presentation, I have divided the marshes into two types—marshes in which there is no evidence to show of the existence of a former lake having a level higher than the present surface of the playa, and marshes in which there is evidence of a former lake with surface higher than the present level of the playa. Examples of these are as follows:

Playas.—Most of the smaller desert basins having small drainage area fall into this class. The small playas north of Reno; the Alkali Flat in Gabbs Valley; Sarcobatus Flat, Amargosa region; Big Smoky playa; and the playas near Mina and Luning.

Marshes (first type).—Rhodes, Teels, Silver Peak, Saline Valley, Fish Lake Valley, Death Valley.

Marshes (second type).—Columbus, Panamint, Sand Springs Flat, Searles, Railroad Valley, Black Rock Desert, Dixie Valley, Alvord Marsh.

The list is not complete and it is evident that the line of demarcation is not a sharp one. Changing climatic conditions might be expected to alter the classification.

MUD PLAYAS.

Playas of this type can not be looked upon as the locus of important accumulations of salines. The small drainage area and the arid climatic conditions would result in little accumulation of ground water and that would be at considerable depth, well without the zone of possible concentration by evaporation. For example, the playa just east of Mina, Nev., contains two wells close to the western edge of the silt area. One well shows water at 112 feet and the other at 114 feet. The water from these wells is used for railroad and town purposes. This example is, perhaps, not as good a one to illustrate the point as could be desired on account of the fact that the underground water probably drains into Rhodes Marsh some 6 miles south and 152 feet lower. Ground water may be looked for at varying depths in almost all playas of this type. What salines are present are, however, at the surface, in thin crusts and efflorescences or concentrated within the upper portion of the silt area in much the same way as was described under the subject of the accumulations of salts in soils.

Desiccation products at depth in playas of this type are more than otherwise apt to be of slight thickness and dubious value. While it can not be said that lakes did not occupy the playas under the humid conditions of the Quaternary, still it can be said that such lakes must have been very shallow and their saline content left by evaporation consequently small in amount. The absence of beach lines and their accumulation of gravel about the playa is, in my judgment, sufficient to warrant the assumption that a lake was either not present or was a shallow one of periodic occurrence.

MARSHES.

The conditions which pertain to marshes of the first type can best be described by examples. R. B. Dole[1] examined the Silver Peak Marsh, Nev. From his account I have taken the main facts. The area is due east of Blair, Nev. The marsh is 32 square miles in extent and is in a basin having an area of 550 square miles. Tertiary volcanics and sedimentaries, limestones, slates, and quartzites of Paleozoic age, and granite and Quaternary and recent alluvium surround the marsh.[1] The climatic conditions are arid. As a result of the examination of the material obtained from bores placed at a number of points on the marsh, Dole describes the structure in the following words:

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[1] Bul. No. 530R, U. S. Geological Survey.

"Brown mud 5 to 20 feet deep forms the upper layer of the marsh. Because of the intense heat the surface of this mud is usually baked dry and hard enough to support the weight of teams. Small scattered tracts have become dry enough to be pulverulent for a depth of 1 to 2 feet, but over the greater part of the playa 4-foot holes are sufficiently deep to strike soft mud. As this layer is composed of very small particles and contains a large proportion of clay, the strong salt waters in it circulate very slowly. The mud contains a great quantity of salt, though the crystals are small. The brines obtained from it are very strong, and the surface is generally covered to a depth of one-eighth to one-quarter of an inch by a white crust of salt that has crystallized from solutions drawn to the surface by capillarity.

"The upper mud along the west shore of the playa, particularly west of the 'islands,' contains nodules of calcareous tufa, which apparently have been formed by deposition of calcium carbonate from the hard waters percolating into the marsh from Mineral Ridge. The record of boring No. 13 shows that clay under the mud west of the 'islands' is underlain by white tufaceous materials, but no salt occurs at a depth less than 41 feet except that in the abundant weak brines.

"Well-defined beds of clay containing crystals of gypsum were penetrated east of Goat 'Island' in borings Nos. 3 and 6, and these are underlain by beds of crystallized salt containing saturated brine. Very stiff black, blue, red, gray, and brown clays underlie the beds of salt or mixed salt and clay in boring No. 3 to a depth of 55 feet, but in boring No. 6 the clays are interrupted by a stratum of gypsum-bearing clay below the salt and a 6-inch stratum of salt at 47 feet, below which clay was again encountered.

"Except a shallow bed of light-gray calcareous material at 16 feet nothing but clay containing weak brine was struck to a depth of 40 feet in boring No. 14, at the south end of the playa.

"Borings Nos. 11 and 12 indicate that the beds of salt in the northeastern part of the marsh are denser than those farther south. The mud is underlain by clay and that in turn by crystallized salt so hard that it has to be drilled. A much harder formation, probably calcareous tufa, was struck below the salt in both borings at a depth of about 36 feet.

"The data afforded by the six deeper borings lead to the conclusion that the northeastern two-thirds of the playa is underlain at a depth of about 20 feet by beds of crystallized salt, 5 to 15 feet thick, mixed with more or less clay. It is doubtful if deposits of so great extent occur west of Goat 'Island' or south of Alcatraz 'Island.' Besides these beds practically all other strata to a depth of 50 feet contain appreciable proportions of salt that readily dissolves in water percolating through them."

It is to be regretted that a greater number of borings were not made and the structure of the marsh more accurately determined at greater depths over the northern half of the basin. In a crude way the structure indicates the following cycle of events:

1. The formation of a lake of unknown depth, but with a surface level below the present level of the marsh. Salines accumulated in this lake, and a general silting up took place. The area of this lake could not have extended much over two-thirds of the area of the present marsh.

2. A period of desiccation in which a thin bed of salt was deposited at a depth of about 48 feet below the present surface. Complete desiccation may not have taken place but concentration sufficient to produce a saturated solution and the crystallization of some of the sodium chloride (bore hole No. 6 shows one-half foot of crystals of salt at 47.5 feet depth). Silts and clays were deposited and covered the layer of salt crystals. Increased rainfall prevented further deposition of salt by diluting the lake waters.

3. The silting up of the lake continued to a level within 38 feet of the present surface. Through the latter part of this period desiccation and consequent concentration of the lake water proceeded simultaneously with the silting up.

4. At this time the concentration of the lake was sufficient to precipitate gypsum (bore hole No. 6, 38 feet, shows gray clay containing gypsum crystals). A period of desiccation followed, and a salt bed was gradually built up reaching a position from 29 to 31 feet below the present level and a thickness of 6 to 7 feet. A period of interruption followed, and then further deposition of salt took place, the extent and thickness of the salt bed increasing. This second layer of salt reached a thickness of 6.5 to 7.5 feet, forming, with the lower layer, a bed in the lowest part of the basin

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[1] For areal Geology see Professional Paper No. 55, Ore Deposits of the Silver Peak Quadrangle, J. E. Spurr.

about 12 feet thick and thinning out on the edges to 6.5 feet. Almost complete desiccation must have marked the end of the period.

5. A greater rainfall changed conditions, and a shallow lake formed. More or less silting and deposition of clay sealed over the salt beds. Desiccation succeeded this comparatively brief interval, and the lake shrunk and deposited a thin layer of salt over a restricted area (2.5 feet of salt in boring No. 12) at a depth of 18 feet from the present surface.

6. A greater rainfall produced a shallow lake, perhaps not more than 10 or 15 feet deep. This lake gradually silted up and slowly evaporated until the present condition was reached.

The lake is dry for perhaps the greater part of the year, and only in the wettest years is water present on the surface. The silting up of the lake must have been accomplished in a large degree by æolian action. The presence of a recent volcanic cone on the western edge of the marsh indicates one of the sources, at least, of the material which filled the lake. The mass of silts and muds filling the lake basin contains a saturated brine.

A chemical examination of the brine indicates the nature of the salines accumulated in this lake bed. From the work previously cited the following table is taken:

Analyses of composite samples of brines—Silver Peak Marsh.[1]

[Parts per 100,000.]

Constituent.	1	2	3	4	9	10
Cl	59.37	59.01	57.35	60.11	59.16	58.32
SO_4	.88	1.70	1.30	.99	1.09	1.61
CO_3	.01	.01	.83	.01	.29	.69
Na	36.12	36.54	32.87	34.65	34.38	34.37
K	2.71	2.26	3.12	2.95	3.69	3.11
Ca	.67	.36	1.92	1.25	.84	1.29
Mg	.24	.11	2.49	.04	.48	.50
Fe Al SiO_2	....	.01	.12	....	.07	.11
	100.00	100.00	100.00	100.00	100.00	100.00
Total solids on evaporation, parts per 100,000	278.76	264.03	48.82	233.44	57.60	39.33

[1] W. B. Van Winkle, analyst. Table recalculated from Bul No. 530R, U. S. Geological Survey.

1. Composite of samples from boring No. 3 at 15.5 feet and from No. 6 at 21 and 40 feet.
2. Composite of samples from boring No. 11 at 27 and 35 feet and from No. 12 at 10, 20, and 27 feet.
3. Composite of samples from boring No. 13 at 16, 31.5, and 40 feet.
4. Composite of samples from boring No. 14 at 11 and 17 feet.
9. Water from boring No. 1 at 6 feet, collected June 1, 1912.
10. Water from boring No. 1 at 27 feet, collected June 4, 1912.

The order of the ions is:

Na	35.14	Cl	58.86
K	2.94	SO_4	1.26
Ca	1.05	CO_3	.30
Mg	.64	SiO_2	.06

Carbonates and sulphates are inconspicuous in amount. The brines consist almost wholly of sodium and potassium chlorides. They are practically saturated. The ratio of sodium to potassium is 11.9. The brines at depth show a somewhat smaller content of potassium than the composite samples. The average is 0.69 per cent of the total solids.[1] Dole gives the analyses of four spring waters tributary to the basin; two are from hot springs and two from cold. These waters have a chemical content very much the same as the brines. They are slightly higher in sulphate radical and average slightly higher in potash content. The sodium-potassium ratio is 10.8.

Certain interesting observations were made upon the brines. In boring No. 12 the brine encountered at 8.5 to 10 feet rose to 1.8 feet (head of 7.45 feet); those at 18 to 20.5 feet rose to 7.5 feet (head of 11.75 feet); those at 22 to 35 feet rose to 8 feet (head of 20.5 feet). A similar condition was noted in bore No. 11 and most of the other bores which penetrated the brine body. These observations indicate the effect of pressure no doubt caused by the elevation of the water plane in the ground water outside the main silt area.

The source of the salines has been discussed by Spurr.[2] He reaches the conclusion that the weak brines discharged by springs around the marsh are the source. Dole suggests that these springs may derive their salines from the marsh itself. Both Dole and Spurr state that the leaching of the Tertiary stratified rocks which are present in the basin in extensive areas accounts for much of the saline residue. If Dole's estimate of the quantity of salt, 15,000,000 tons, be taken, and the area of the basin considered, 1.9 pounds per square foot of the basin surface would account for this quantity. It would not be unreasonable to expect this to be derived from the erosion of the Tertiary sedimentaries and volcanics, especially when we consider the great amount of erosion which has taken place in Clayton Valley. Spurr points out, however, the conspicuous absence of borates in the salines of the Silver Peak Marsh and their presence in the neighboring playa to the west—Fish Lake Valley. In both localities Tertiary sediments are common. He rightly reasons that if these sedimentaries were responsible for the salines, borates would also be present in the Silver Peak salines. His conclusion that the salines of the Silver Peak Marsh are derived from hot springs at the edge of the playa would not account for the absence of borates at depth. Three possible hypotheses suggest themselves: The absence of the "borate member" in the Tertiary sedimentaries of the Silver Peak Basin and its presence in the Tertiary sedimentaries tributary to Fish Lake Valley; deeper borings in the Silver Peak Marsh might reveal borates; the volcanic activity in the Silver Peak Marsh was not characterized by emanations of boric compounds.

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[1] Bul. No. 530R, U. S. Geological Survey, p. 14.

[2] Professional Paper No. 55, U. S. Geological Survey.

The source of the borate compounds in Tertiary sedimentaries is generally conceded to be due to contemporaneous vulcanism. This must have been local and would result in localization of boraciferous strata in the Tertiary series. This leads me to favor the first hypothesis. I do not, however, consider the question settled, and further data must be obtained before it can be.

I am inclined to the view that the major part of the salines were derived from the erosion of the rocks of the basin; that possibly recent volcanic activity was responsible for a part also; and that much of the present surface accumulation is due to the springs and seepage water.

Dole estimates the quantity of salt in the Silver Peak Marsh as 15,000,000 tons within the first 40 feet. The deposit has commercial possibilities for the production of salt. The average of the analyses upon the four brine composites shows 2.76 per cent potassium in the anhydrous residue. This is equivalent to 5.2 per cent potassium chloride. It is doubtful whether this is high enough to warrant the attempt to separate the potassium salt. The association of the brine with compact muds would prevent it from freely flowing to a bore hole. There would be, therefore, some difficulty in obtaining sufficient brine from a few bore holes to supply evaporating vats. The small amount of carbonate and sulphate would render the problem of the separation of the sodium and potassium chlorides comparatively simple. The production of sodium chloride with a by-product rich in potassium chloride is not beyond the possibilities of commercial exploitation.

Conditions in Rhodes, Teels (Pl. I, fig. 1), Fish Lake Valley, and Saline Valley are very much the same as in Silver Peak Marsh. Undoubtedly shallow lakes occupied each of these basins, and the filling-in process and the desiccation of the lakes must have been similar. Unfortunately the results of systematic boring are not obtainable. No doubt each of these presents individual characteristics and differs in some details from the example described. The most marked difference is in the presence of borates.

In Fish Lake Valley, Turner states that there are four playa deposits, all of which have been worked for borax. Analyses by G. Steiger show in one case chloride, sulphate, carbonate, and borate of sodium. In another, sulphates and borates of calcium and sodium. No mention is made of potassium in the analyses.[1]

The conditions at Rhodes Marsh have been described by LeConte.[2] His observations are summarized below.

The central area is occupied by a salt crust consisting of almost pure sodium chloride. About the salt area and below the surface soil is a comparatively thick bed of sodium sulphate. Sodium carbonate occurs in soft crusts 2 or 3 inches thick, but is not general. Borax and ulexite also occur. The ulexite is in the form of nodules imbedded in wet, stiff clay in the semicircular area surrounding the central salt area on the north, northwest, and northeast. The borax occurs on the west, southwest, and southeast of the central salt area. It is in a moist, stiff clay which is full of the transparent crystals. It also occurs as a crust from 1 to 3 inches thick. This crust renews itself. The localization of the salts is attributed to the action of springs, and the concentration of the pure sodium chloride in the lowest part of the playa is attributed to the leaching of this compound by surface waters. It is evident from the description that the salines in the marsh are much more complex than those in the Silver Peak area. The regional rocks are similar to those about Silver Peak. The playa is of special interest in that it more nearly approximates the ideal type described before than any other. It is a circular basin of 232 square miles area, occupied by a playa of 3.2 square miles area. The ratio of basin area to playa area is 72.5. It receives its principal underground waters from the Sodaville-Mina Valley. Undoubtedly its history is similar to the Silver Peak Marsh. The central area is occupied by a reddish-brown mud, locally covered by efflorescences. In places the mud is dried to a brown, pulverulent soil, containing more or less sodium chloride and small amounts of other salines. The present movement of the salines from the deeper beds is taking place, first, by slow upward movement of the water contained in the muds (caused by capillarity), and, second, in the marginal portions by a slow movement upward caused by capillarity and by the banking up of the water plane where it strikes the more or less impervious mud bodies of the central playa. The water of the central area is saturated with salines and deposits them as crusts at the surface. In the marginal portions the underground water becomes more or less saturated as it passes through the beds and carries saline material to the surface, where it crystallizes out. LeConte's idea in a large measure is correct. His term "springs" would include seepage water in all its phases of upward movement. Occasional heavy rainfalls produce sufficient run-off to form a shallow lake. Such waters dissolve salines and concentrate them in the central depression. Salt is the principal compound concentrated in this manner.

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[1] Professional Paper No. 55, U. S. Geol. Survey, pp. 158, 159, Spurr.
[2] Third Annual Report State Mineralogist of California, 1883.

A number of analyses were made upon samples of salines from this marsh, but potassium in small amounts only was found. A sample of moist sand and salt from the central part of the playa shows the following:

Analysis of salt in sand from playa, Sample No. 15.

[Analysis by J. A. Cullen.]

	Per cent.		Per cent.
Ca	1.20	SO_4	47.68
Mg	.44	Cl	14.17
K	3.03	CO_3	3.09
Na	30.39	Total soluble salts in sand	12.15

The analysis shows sodium sulphate and chloride in greatest amount. Minor amounts of sodium carbonates and some potassium chloride are shown. The sodium-potassium ratio is 10. No analyses of the brines are available. Excepting for the borax and salt, this marsh is a very doubtful source of commercial salines. The potash content is too low and its separation would be complicated by the presence of sulphates and carbonates.

Saline Valley, Inyo County, Cal.

This is an inclosed basin. The central portion, of about 12,000 acres extent, is covered by a salt crust 2 inches thick and beneath are muds saturated with brines. When the crust is scraped off it renews itself in about 15 days. At almost any place over the salt area at a depth of 2 feet salt brine can be obtained. In warm weather the salt crystallizing out is pure; in cold, it contains small amounts of soda. The salt deposits are being worked and preparations are being made on a large scale for its shipment by the Saline Valley Salt Co. The regional rocks about this basin are granites, limestones, and volcanics. Marsh borax was worked at one time in the valley.

A single sample of the salt crust from this valley was submitted and found to contain 40.98 per cent soluble salts, and the soluble salts contained 4.2 per cent potassium. Three brines and one spring water were also submitted. The analyses follow:

Analyses of brines and spring water from Saline Valley.

[Per cent of total solids.]

No.	Ca.	Mg.	Na.	K.	CO_3.	HCO_3.	Cl.	SO_4.	Total solids on evaporation, parts per 100,000.
1	10.0	3.08	13.84	Tr.	Tr.	7.64	24.62	28.46	130
2	.18	.37	36.31	1.17	.07	.03	48.78	12.85	35,506
3	1.55	.79	34.38	.73	Tr.	.15	48.70	13.37	8,237
4	2.97	.73	32.57	.71	Tr.	.28	45.45	17.30	4,238

No. 1. Spring water.
No. 2. Brine from center of flat.
No. 3. Brine from pothole on south edge of flat.
No. 4. Brine from pothole one-half mile east of No. 3.
Analyses by J. A. Cullen, Bureau of Soils.

Sufficient data are not available properly to characterize this area. It is not unlike the Silver Peak Marsh. The potassium content of No. 2 brine, the highest, is less than for the average of the Silver Peak brines. The high content in the single sample of the crust material is not considered significant, since samples of this material occasionally run high in potassium.

DEATH VALLEY.

Death Valley receives the drainage of the Amargosa River. The drainage area is given as 23,160 square miles by Free's table of basin areas. The area of the playa is approximately 160 square miles, not including Mesquite Valley in the northern end. The ratio of basin to playa is 144 to 1.

The valley lies between the Panamint Range on the west and the Amargosa Range on the east. It has a length of 120 miles and a width varying from 3 to 10 miles. Much of the valley area lies below the sea level. The lowest point on the topographic sheet is −280 feet. Ball states that some 15 miles farther south from this point the depression is 125 feet deeper. The Panamint Range reaches its maximum elevation at Telescope Peak, 11,045 feet, an air-line distance of about 12 miles from the −200-foot contour of Death Valley. The Amargosa Range reaches an elevation of 6,397 feet at Funeral Peak, a distance of 6 miles from the −200-foot contour; 6,725 feet at Pyramid Peak, a distance of about 12 miles from the −200-foot contour; and 5,420 feet at Chloride Cliff Peak, a distance of 10 miles from the −200-foot contour in Death Valley. The Panamint Range averages from 7,000 to 9,000 feet altitude and the Amargosa from 6,000 to 7,000 feet. The maximum grade on the west from Telescope Peak to the valley is 920 feet per mile (9.8°), and on the east, measured from Funeral Peak, 1,066 feet per mile (11.4°). The canyons leading to the valley do not approximate these grades, except in their upper ends, but the average grade is very steep. In consequence of these steep grades and the torrential character of the occasional rain storms, alluvial fans and mountain aprons have been developed on a vast scale. The narrowness of the valley has resulted in the development of a structure similar to that shown in figure 4. Undoubtedly many of the fans overlap beneath the central basin.

The floor of the valley is level, but on the flanks are low hills, some of Tertiary sediments (Pl. I, fig. 2), and some of alluvial material representing the residual portions of alluvial fans attacked by recent erosion. Mesquite Flat, in the northern end of the valley, is covered with sand dunes. There are no positive evidences of a lake during Quaternary times. Some evidences of a shallow, recent lake in the area east of Bennetts Wells are discernible in faint shore lines, which indicate a depth of 6 to 12 feet.

An enormous deposit of salt occupies the lowest depression. The salt area begins south of Salt Creek, 6 miles northwest of United States land monument No. 34, and extends to a point south of Mesquite Spring. The length of the salt area is from 30 to 32 miles, and its width ranges from 2 to 4 miles. Over a large part of this area the salt appears as a crust composed of pinnacles and fantastic, twisted masses. (Pl. II, fig. 1.) It is said that some of the rough salt pinnacles reach a height of 6 feet. The average height of those I saw would be from 1½ to 2 feet. The thickness of the rough salt varies. Campbell[1] states that it can not be less than 1 foot thick. Free states that the thickness of the upper crusts is 18 inches. Below this is 3 feet of mud, then 18 inches of salt, and then mud to 10 feet at the place where he tested.

In the so-called sink east of Bennetts Wells and about 18 miles south of Furnace Creek Ranch is an area of smooth salt. (Pl. II, fig. 2.) On the eastern edge of the valley this is separated by a narrow rim of mud and rough salt from the alluvial wash of the Amargosa Range. On the north the area is bounded by rough salt which extends across the floor of the valley. The first foot of the smooth salt area is composed of layers of crystalline salt 2 or 3 inches thick, separated by thin seams of mud and sand. Brine comes to within a fraction of an inch of the surface. A slight scraping of the surface is followed by the flowing in of the brine. The surface of the salt is divided into small polygonal areas by thin cracks through which the underlying brine has been drawn and in crystallizing has left low welts of crystallized salt cementing the cracks together. As far as I have been able to ascertain, no measurements of the thickness of this salt have been made. B. K. Brockington estimates that the total area of incrustation is approximately 150 square miles. Of this about one-third, or 50 square miles, is smooth salt, the greater part of this being in the sink east of Bennetts Wells.

In the rough salt area, holes show a brine to be within 1 or 2 feet of the surface. Within this area also occur potholes, circular openings from 2 to 4 feet in diameter and of varying depth and filled with brine. (Pl. III, fig. 1.) The interior of the holes is lined with salt crystals. About the edges, surface tension has drawn the brine up and the margin of the hole is crusted with efflorescences of salt. Near the "land" edge of the rough salt area many holes are to be seen, some more or less arched over by salt crusts and dry mud, and always containing water. Areas of soft red mud also occur between the rough crusts and the outer margin. These are often difficult and dangerous to cross. The formation of the rough salt crusts may often be seen upon these mud areas. The explanation appears to be as follows: The surface mud dries, forming cracks, and in shrinking leaves narrow channels, bottomed by soft mud, between the cracks. Through these channels the brine solution slowly passes up and crystallizes, forming veins of salt. As the mud cakes dry, they curl upward on the edges, opening the channels wider and allowing more brine to work upward. This crystallizes in part and in part is drawn by surface tension over the surface already crystallized, forming thicker crusts. The brine in the soft mud below is steadily supplied, and the crusts build up until they practically seal the brine over. More or less evaporation must continue beneath the crusts, and as the salt crystals form they must crowd the mud and crusts up, forming the characteristic windrows of mud and salt on the marginal portions. The slow consolidation of the mud, as well as the banking up of the ground water on the periphery against the mud mass, would account for the upward movement of the brines. Rain water would dissolve the salt from the crusts thus formed, and it would collect in small puddles between the roughened masses, where it would be evaporated to a brine. Surface tension would draw this brine up upon the rough masses of salt and, evaporating there, would thicken and build up the irregularities of the salt. The evaporation of a salt solution in a beaker and the climbing of the salt up the sides is a familiar laboratory phenomenon.

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[1] Bul. No. 200, U. S. Geol. Survey, p. 18.

The smooth area of salt is built up by fresh accessions of brine coming from the action of rain water upon the neighboring rough salt areas. Shallow channels (sloughs) meander through the rough salt and collect part of the brine formed by the occasional rains, discharging it upon the smooth salt, where it is speedily evaporated. Wind-blown material collects in the thin sheets of brine and mingles with the salt crystals. The general admixture of soil impurities in the rough salt is also explained in this way. It is evident that the smooth salt area would eventually reach a level that would permit little or no drainage to collect, and the salt bed would no longer be built up. Slow consolidation of the silts and clays in the lowest depressions would extend the differentiation of level over a long period. Differential consolidation would be expected in an area like Death Valley. The finest clays and silts in the lowest depression or sink would consolidate at a greater rate than the sand and alluvial material forming the greater part of the Death Valley filling. The consolidation of the clays and muds would be expected to force the solution upward and even outward. The brines forced outward would be diluted by mingling with the underground waters coming from the neighboring watersheds. We would expect the marginal water to be lower in saline content than that in the smooth salt area, and samples and analyses show this to be the case. Reference is made to the results of samples Nos. 339, 341, and 342. The sample No. 339 was taken on the west side of the valley, due west of Furnace Creek Ranch; No. 341 was taken one-fourth mile east of No. 339, and No. 342 one-quarter mile east of No. 341. They show, respectively, 2.77, 15.12, and 34.18 grams total solids per 100 cubic centimeters.

Campbell states that Death Valley is one of the best watered areas within the Amargosa region and that the water is, for the most part, good. An inspection of the topographic sheet shows many of the water holes to be close to the edge of the central playa. At Bennett's wells the water is within 1½ feet of the surface. Most of the wells are shallow. The explanation of this has been given under the structural development of a playa.

CHEMICAL DATA FOR DEATH VALLEY.

Four sets of analyses are given in Tables XXI, XXII, XXIII, and XXIV (Appendix). The composition of the brines in Table XXI gives perhaps the best conception of the character of the salines present in Death Valley. The average percentage of ions based upon the percentage of total solids in the order of their magnitude is Na, 36.12; K, 2.63; Mg. 0.3; Ca, 0.2; Cl, 53.7; SO_4, 5.62; CO_3, 0.18. Sodium and chlorine are the dominating ions. Carbonates are insignificant in amount. The sulphates are in greater amount than in the Silver Peak brines. Potassium is in smaller amount than the Silver Peak brines. The sodium-potassium ratio is 13.7; in the Silver Peak brines it is 11.9. These ratios indicate parallel conditions in both places. Calcium and magnesium are insignificant in amount. It should be noted that there is comparative agreement between the results obtained upon samples taken by different persons.

B. K. Brockington submitted several brines to the Cooperative Laboratory from this locality, and the results upon these closely corroborate the samples taken by Free and Jones.

It should be noted also that borate compounds are found in Death Valley; just north of Bennett's Wells is the Eagle Borax Works, now abandoned. Surface crusts were gathered at this place and refined. North of Furnace Creek Ranch is an old borax mill. The playa in the vicinity was the source of the borate minerals. This deposit is practically at the mouth of Furnace Creek. The well-known deposits of colemanite in Furnace Creek Canyon were undoubtedly the source from which the marsh borax in the valley came.

The borax deposits in Death Valley are no longer worked. No salt has been produced on account of difficulty of access and climatic conditions. The potassium content of the brine is probably too low to warrant attempts at separation. Until deeper borings are made in the smooth salt area and the composition of the brines at depth determined, Death Valley must still be looked upon as a possible source of potassium salts. It is, however, a matter of reasonable doubt whether a greater content of potassium will be found at depth. Death Valley is of interest in that it indicates a transition stage in the formation of a saline deposit at depth. It would not take a very great increase in rainfall to bring down débris sufficient to cover and seal the present salt deposit.

Since the foregoing was written the results of borings and analyses upon the brines obtained therefrom by the United States Geological Survey became available and are given below.

Log of United States Geological Survey boring No. 3, Death Valley, Cal.

	Feet.
Salt (1½ inches thick on surface).	
Mud, light brown, containing coarse salt crystals	1.5
Salt layer 2 inches thick with flow of brine at bottom.	
Mud, soft brown	29.0
(Small flow of warm water at depth of 30 feet.)	
Mud, yielding seepage of water	2.5
Clay or mud and crystals of salt	1.5
Salt	.5
Mud, black, and crystals of salt	1.5
Salt	.5
Mud, black, and crystals of salt	15.0
(Water all shut off and auger cut without seepage.)	
Salt	.3
Clay, black, with occasional thin salt layers	3.7
Salt, crystalline, hard, containing layers of black clay mixed with salt crystals 1 to 4 inches in thickness at intervals of about 2 feet	8.5
Mud	.5
Salt, crystalline, apparently solid	13.0
Mud	2.2
Salt, crystalline	3.8
Clay, black	1.0
Salt, crystalline	2.0
Clay, black, containing salt crystals	10.5
(No water encountered in the lower part of the well.)	
Total	96.0

Analyses of potash in natural brines from Death Valley, Cal.

[W. B. Hicks and R. K. Bailey, analysts.]

Description of sample.	Depth in feet at which sample was taken.	Total salts (ignited residue) expressed as percentage of original solution.	Potash (K_2O) expressed as percentage of ignited residue.	KCl expressed as percentage of original solution.
Ground water in the salt crust at the "sink"	0.5	28.19	3.43	1.53
Water in open "pothole"	.5	27.47	1.20	.52
Do	9.5	27.48	1.18	.51
U. S. Geol. Survey well No. 1	6	27.87	2.85	1.27
Do	24	28.64	2.22	1.01
Do	29	28.96	2.35	1.09
Do	52	28.66	2.01	.91
U. S. Geol. Survey well No. 2	32	28.33	1.54	.69
Do	38	29.16	1.78	.82
Do	70	29.96	2.48	1.18
U. S. Geol. Survey well No. 3	1	27.78	2.05	.90
Do	30	27.91	1.68	.74
U. S. Geol. Survey well No. 4	32	28.77	2.23	1.02
Do	38	28.73	2.12	.97
Average		28.42	2.08	.94

Gale comments upon these results as follows:

"No shore markings or other evidence of former deep submergence of Death Valley have yet been discovered. It appears that the deposits laid down in this valley have been chiefly the results of temporary shallow submergences and alternate desiccations. Thus the deposits that make up the floor of this valley are supposed to have been built up layer by layer, the salts having crystallized from the water evaporated from the temporary shallow lakes and having been occasionally buried in mixtures of sand and silt, including more or less saline material swept in by occasional floods. This is the process that is going on at the present day.

"A vast amount of saline material is accumulated in the bottom of this valley, but the mode of its deposition probably is not favorable to selective crystallization on a large scale. Segregation of potash or any other portion of the soluble constituents of the waters may have taken place to slight extent in the individual salt crust layers, but under the conditions described any such differentiation is likely to have been restricted to the individual layers as units, and therefore has occurred on a scale so small as to be of doubtful practical importance. It seems evident that unless a vast body of saline material has been deposited at one time during a single period of desiccation that there would be little chance for the various dissolved constituents to become segregated one from another on a large scale. There is no record of the drying up of a single large lake of saline waters in Death Valley. Although it is possible that the shores of such a lake might have been completely buried, the assumption that this may have happened must be purely a matter of speculation."

The potassium content of the saline residues from the brines obtained from the United States Geological Survey bores is lower than the average for the brines obtained from the surface potholes, the figures being, respectively, 1.73 and 2.63 per cent. There is practical agreement in the results since some concentration of the potassium salts might well be looked for in the surface brines.

While the results of the Survey's work in Death Valley are disappointing, they are of considerable importance, as they give much information concerning deposits of this character. The conditions at depths greater than 100 feet are unknown, but it is fair to presume that they are not unlike those within the first 100 feet. Salines in vast quantity have collected in Death Valley, but concentration of the most valuable salines has not taken place on anything more than a very local scale. For the concentration of these salines extreme conditions of aridity must be looked upon as unfavorable. A deep lake, existing for some considerable time and then quickly drying up, appears to be the condition necessary for the concentration of the most soluble salines.

Marshes of the Second Type.

Marshes of the second type have a special interest in that the presence of a former lake indicates a much greater run-off, and consequently a greater amount of saline accumulations. The desiccation of such a lake would be more apt to produce workable beds of salines than marshes of the first type. Descriptions of Searles and Columbus Marshes, Railroad and Dixie Valleys, Sand Springs Flat, and Sevier Lake follow.

SEARLES MARSH.

Searles Marsh lies in the northwestern part of San Bernardino County, Cal., about 30 miles northeast of Randsburg. It lies in a drainage basin of 4,850 square miles area. C. E. Dolbear states that the area of the central depression is about 62.5 square miles. This would give a ratio of 77.6 square miles of basin area to 1 square mile of central depression area. The lowest part of the depression is 12 square miles in area, and is occupied by a smooth, hard floor of salt (Pl. III, fig. 2). Portions of the area are covered by débris; other portions by efflorescences and crusts from a fraction of an inch to several feet in thickness; and other portions are covered with clay muds which are in part dried out and firm and in part are soft. Plate IV, figure 1, shows a trona reef in the northeastern part of the marsh. De Groot[1] reports results of a boring and shows a section of the marsh. Dolbear[2] quotes the results of two bores, one in the central salt area and the other in the marginal area outside of the salt bed.

Section of Searles Marsh (De Groot).

Depth.
2 feet......Salt and thenardite.
4 feet......Clay and volcanic sand with some hanksite.
8 feet......Volcanic sand and black clay with bunches of trona.
8 feet......Volcanic sand containing glauberite, thenardite, and a few crystals of hanksite.
20 feet......Mud smelling of hydrogen sulphide and containing layers of glauberite, soda, and hanksite.
28 feet......Solid trona overlain by a thin layer of very hard material.
230+feet......Clay, mixed with volcanic sand and permeated with hydrogen sulphide.

Analyses of samples from borings in Searles Lake.

[Analyses by Dolbear.]

Depth.	Insol.	NaCl.	Na_2SO_4.	Na_2CO_3.	$NaHCO_3$.	$Na_2B_4O_7$.	H_2O.
Feet.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P.* ct.	*P. ct.*
0–18	0.2	79.7	7.6	3.2	0.0	Tr.	3.3
18–25	1.4	44.0	30.5	14.8	2.5	1.0	5.8
25–30	1.4	47.3	28.1	10.6	.0	2.0	10.6
30–35	3.0	42.7	17.1	19.1	5.9	2.0	10.2
35–50	1.4	43.5	22.3	9.5	2.5	5.5	15.3
50–65	Tr.	82.8	10.6	3.2	.8	Tr.	2.6
65–79	Tr.	19.0	7.3	40.3	18.5	.5	14.4

Analyses of samples from borings outside of salt-bed area.

[Analyses by Dolbear.]

Depth.	Insol.	NaCl.	Na_2SO_4.	Na_2CO_3.	$NaHCO_3$.	$Na_2B_4O_7$.	H_2O.
Feet.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
0–13	Mud.	....	....	....	....	....	....
13–20	8.3	66.8	1.0	11.7	5.0	0.4	6.8
20–25	Tr.	98.4	.8	1.8	.0	.0	.0
25–30	1.4	15.3	4.7	38.7	24.4	Tr.	15.5
30–35	15.0	39.6	2.3	16.4	3.4	5.56	12.74
35–40	33.4	17.5	3.9	14.85	4.7	5.6	20.05
40–45	36.0	9.8	2.9	12.5	.4	6.57	26.28
45–50	32.5	9.0	2.6	21.2	3.8	.0	30.9
50–53	30.7	8.3	2.8	23.3	7.6	Tr.	27.8
53–55	31.0	9.0	2.8	21.2	10.9	.0	25.1
55–60	26.9	5.8	1.9	26.5	14.3	Tr.	24.6
60–65	3.2	4.5	38.0	28.6	10.1	Tr.	10.6
65–70	6.8	5.1	6.8	43.5	21.0	Tr.	16.8
70–75	7.6	4.0	2.8	53.0	16.0	.0	16.6

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[1] 10th Annual Report, California State Mining Bureau, p. 535.

[2] Engineering and Mining Journal, Feb. 1, 1913, p. 260.

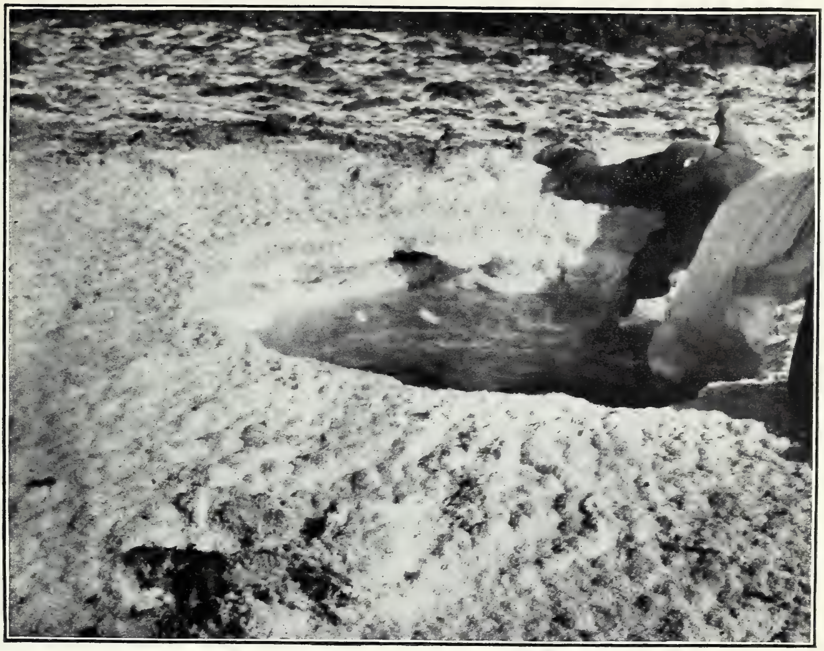


FIG. 1.—POT HOLE, DEATH VALLEY—EAST SIDE; EAST OF BENNETTS WELLS.

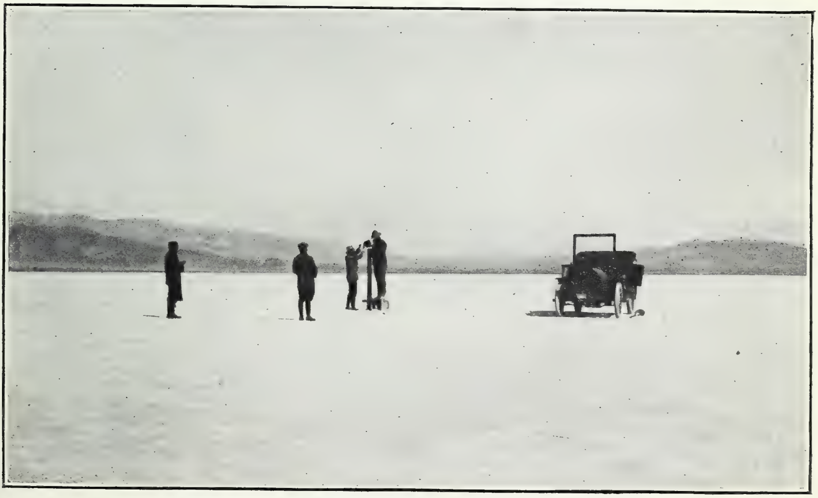


FIG. 2.—SEARLES MARSH, CAL. MAIN SALINE DEPOSIT.

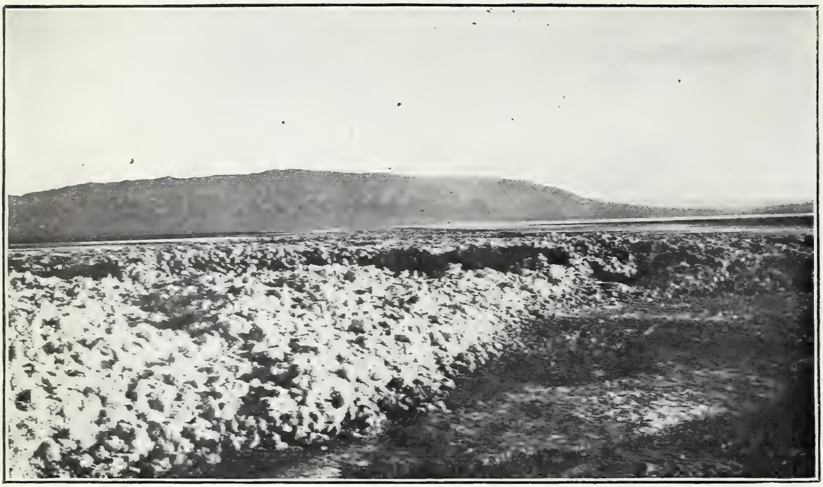


FIG. 1.—SEARLES MARSH, CAL. TRONA REEF IN NORTHEAST CORNER.

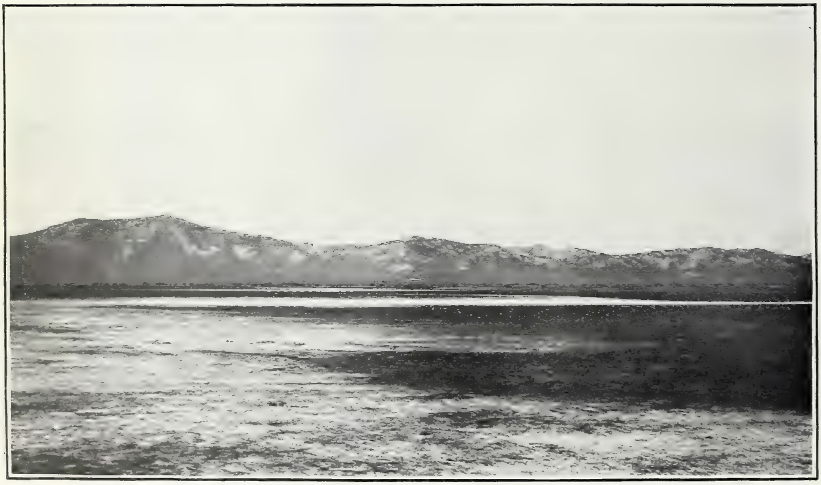


FIG. 2.—RAILROAD VALLEY, NEV. SALT PAN AT NORTH END.

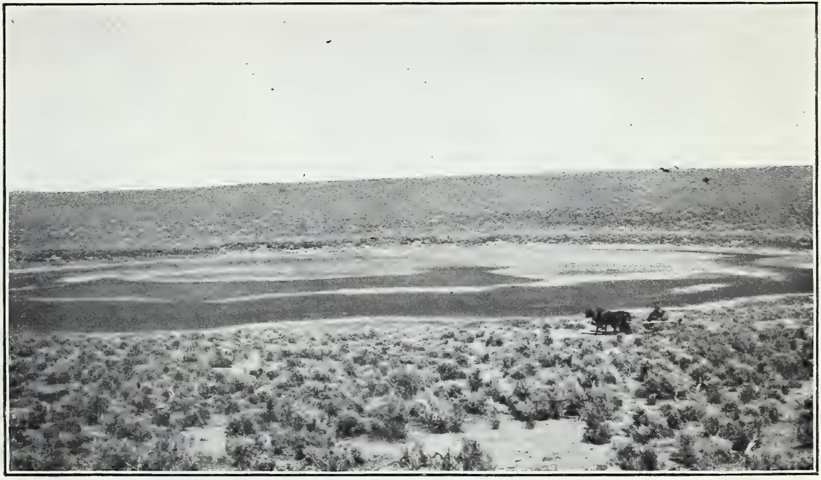


FIG. 1.—LAVA PLATEAU WEST OF ALKALI LAKE, OREG. SMALL INCLOSED PAN.

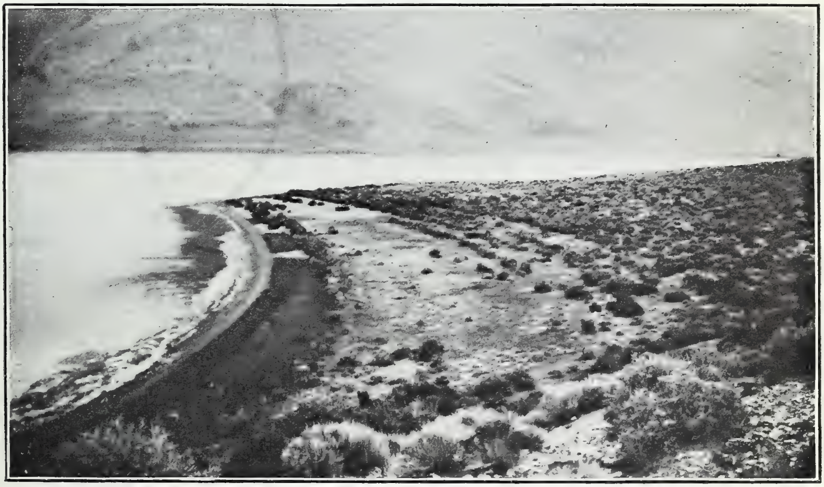
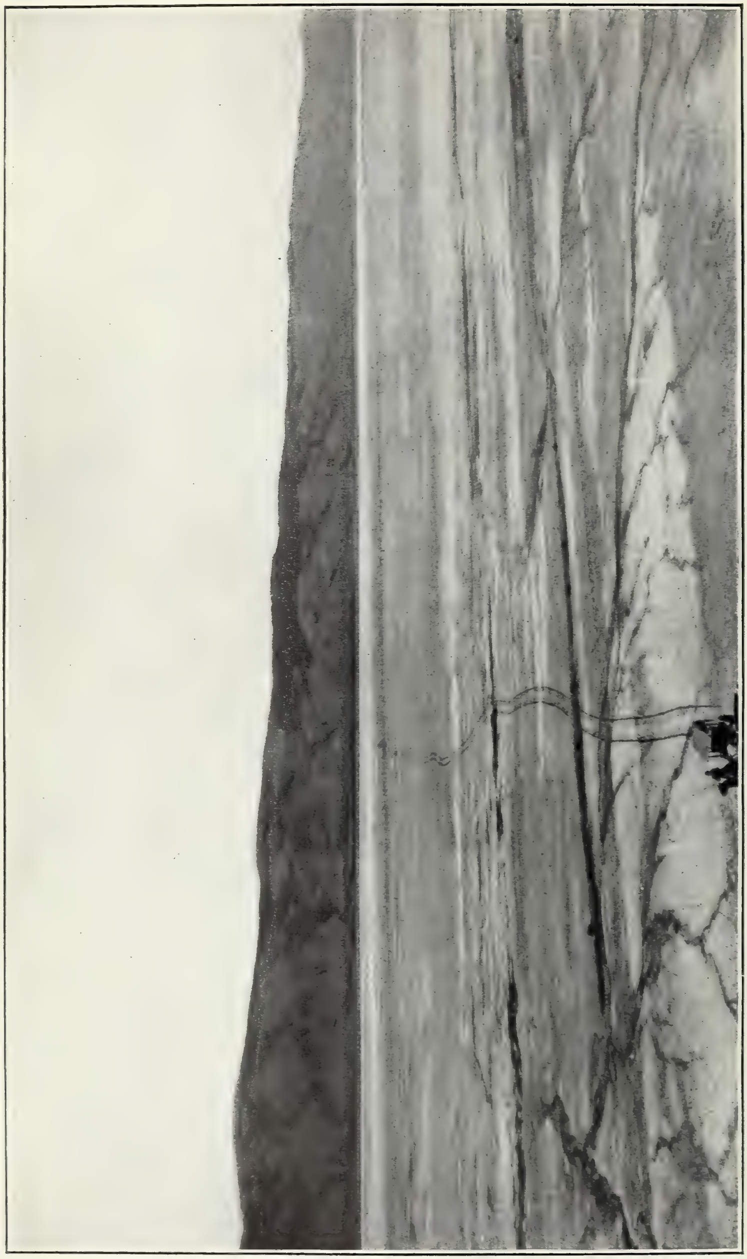


FIG. 2.—ABERT LAKE, OREG. SHORE AT SOUTHEAST CORNER.

PLATE VI.



SURPRISE VALLEY, OREG. PLAYA OF UPPER LAKE.

Through the kindness of Dennis Searles, E. E. Free obtained the samples from a bore put down over 600 feet in the area northwest of the central salt area and near the road leading from the plant of the California Trona Co. southeast of the salt area. The exact location of this deep bore is not known. The series of samples is not complete, and the notes accompanying them are also somewhat incomplete. The results of analyses upon these samples are given in the accompanying tables. Table XXV (Appendix) gives the total sodium and potassium, soluble sodium and potassium, and insoluble sodium and potassium. Table XXVI (Appendix) gives the ratios of soluble sodium to potassium, of insoluble sodium to potassium, and of total sodium to potassium. Tables XXVII (Appendix) and XXVIII (Appendix) show respectively the percentage composition of the samples, and of the water-soluble material contained in the samples. Accompanying is a brief description of a petrographic study (Table XXX, Appendix) upon the samples of the deep bore by J. C. Jones. It is unfortunate that the record is incomplete, but incomplete as it is, the results of our examinations are of sufficient interest to warrant presentation.

Before discussing the foregoing data, it is necessary to establish certain criteria by which we may determine the nature of the events which took place during the history of this lake.

The progressive or fractional crystallization of brines and salt solutions has been thoroughly discussed by Turrentine.[1] On account of the similarity of conditions, I have deemed it best to take the results which T. M. Chatard obtained in his experiments upon the waters of Owens and Mono Lakes. These results are shown graphically in figure 6.[2] The waters from both lakes are similar in composition. Mono Lake water has a slightly higher percentage of sodium sulphate than Owens. The water in both cases contains carbonates, bicarbonates, sulphates, chlorides, and borates; also sodium, potassium, and minor amounts of silica, calcium, magnesium, alumina, and ferric oxide. The temperature conditions in the evaporations range from 18.3° C. to 37.8° C. The two sets of experiments indicate similar results. The following are the criteria from these experiments:

1. At initial stages of evaporation calcium carbonate, mixed with more or less ferric oxide, would be precipitated.
2. Saturation would be indicated by a crystalline deposit in which carbonates would predominate. Sulphates would be least and chlorides would be present in moderate amount only. Potassium chloride would be less than 1 per cent of the saline deposit. The ratio between sodium carbonate and bicarbonate in the deposited salines would approach unity.
3. Succeeding stages would be marked by decreasing amounts of carbonates and increasing amounts of sulphates and chlorides. The ratio between sodium carbonate and bicarbonate would rapidly increase. At an intermediate stage sulphates would reach a maximum. Sodium chloride would remain in about the same proportion, or would be slightly increased.
4. Approach to final desiccation would be indicated by the separation of a large proportion of sodium chloride and a small increase in the proportion of potassium chloride.
5. Final desiccation would yield relatively small amounts of sulphates and a larger proportion of chlorides and carbonates. Some borates would be present. The sodium-carbonate and bicarbonate ratio would reach a maximum value, and relatively large proportions of potassium salts would characterize this state.

Four terms may be designated to indicate the progressive stages, and in their natural order are:

(1) The trona period—sodium carbonate and bicarbonate in about equal amounts preponderate;
(2) The sulphate period—separation of sodium sulphate;
(3) The sodium chloride period—maximum proportions of sodium chloride;
(4) The complete desiccation period—maximum percentage of potassium chloride and presence of borates.

In the case of the uninterrupted desiccation of a saline lake the successive stages mentioned above would grade insensibly one into the other. The actual case would be further complicated by temperature variations, seasonal and periodical, by interruptions caused by the dilution of lake waters, by rainfall and stream discharge, and by silt, mud, and æolian deposition. Wind and wave action would tend to thicken the shore deposits. The thinning out of the lake waters at the margin would set up there more favorable conditions for crystallization than in the deeper portions. In the marginal portions silt deposits would be greatest, and the salines deposited here would be characterized by a large proportion of insoluble material. In a single large basin the lake during evaporation might be divided into several smaller lakes, and each would have its individual conditions and in each case would form saline deposits differing from the others. Lastly, the nature of the salines would be expected to differ in different lake basins. The proportions between chlorides, sulphates, carbonates, bicarbonates, and the basic ions present would vary somewhat from the two samples chosen for establishing our criteria.

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[1] The Occurrence of Potassium Salts in the Salines of the United States. Bul. No. 94, Bureau of Soils, U. S. Dept. of Agr.

[2] Data for this figure were taken from Bul. No. 60, U. S. Geol. Survey, pp. 59–65.

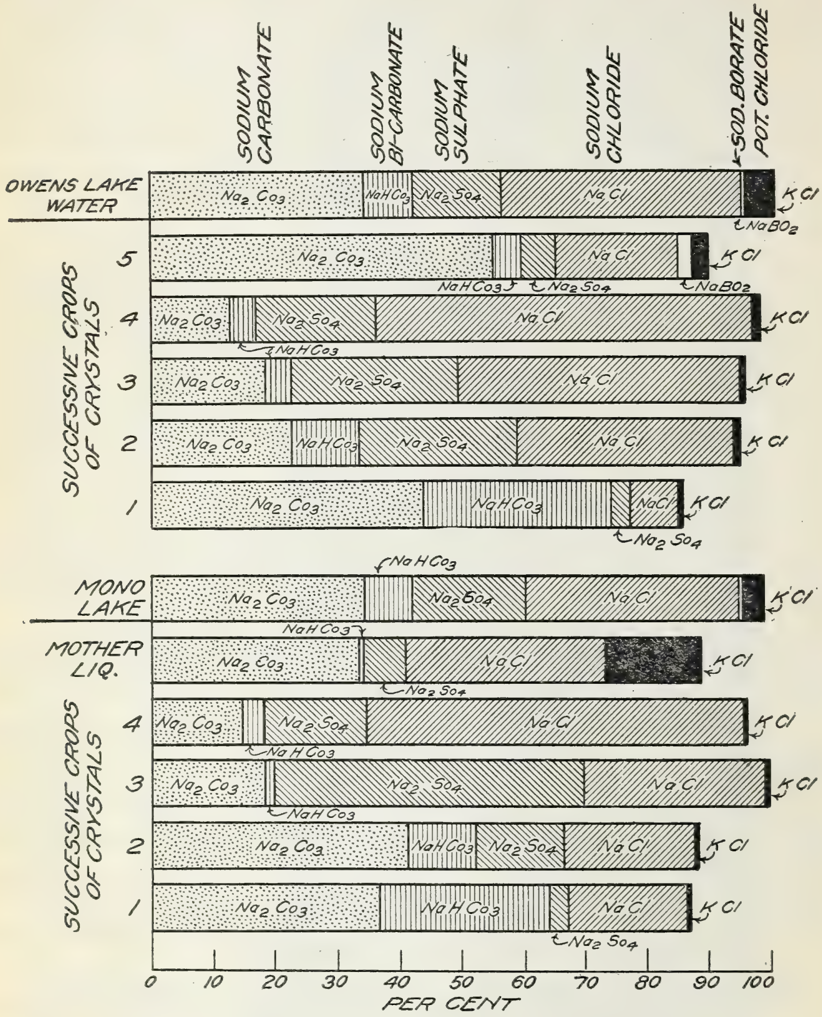

FIG. 6.—Order of deposition of salts in Owens Lake and Mono Lake.

Another condition requires discussion. Salines are deposited upon and in lake bottoms. The lake sediments would include saline waters and, as desiccation proceeded, the lake sediments would include waters containing gradually increasing amounts of saline material. When saturation is reached not only would brine be expected but individual crystals of the different salts would also be so included. If crystallization proceeded faster than sedimentation, the lake sediments would contain larger and larger proportions of saline material. If sedimentation proceeded faster than crystallization, smaller proportions of saline material would be expected. It is evident that crystallization must proceed at a comparatively slow rate under natural conditions at the beginning of desiccation, and, as desiccation proceeds, the rate of crystallization must increase to a maximum. Final desiccation of the mother liquors must be a long drawn-out process, if at all completed. It is not impossible to expect that at this stage of desiccation sedimentation by æolian action might proceed rapidly enough to absorb the final mother liquor. The crystalline mass formed during the final stages of desiccation would also absorb portions of the mother liquor at the end.

The saline content of a mud, assuming that it has absorbed a brine which is saturated and at point of crystallization, has been calculated in the following: A wet mud with a specific gravity of 2 and composed of mineral particles 2.6 would have a void space of 37.4 per cent by volume. If 1 cubic foot were filled with a brine of specific gravity 1.25, the brine would weigh 29.3 pounds. Chatard's experiments on the Owens Lake water showed a brine of 1.26 specific gravity at incipient crystallization; and this contained 30.56 per cent by weight of salines. The brine filling 1 cubic foot of the mud would contain approximately 9 pounds of salines. This would be equivalent to 8.1 per cent of the weight of the dry mud.[1] Dry mud samples containing an excess of 8.1 per cent of saline material would indicate saturated solution conditions with some crystallization and deposits of salines; less than 8 per cent it would be concluded that the mud had captured an unsaturated brine.

If it is assumed that the mass of saline crystals would contain a void space of 30 per cent of its volume and the resulting mother liquor had a specific gravity of 1.3, the weight of the brine solution contained in 1 cubic foot would be 24.4 pounds. If we assume the specific gravity of the salines to be 1.9, the weight of the brine absorbed would be 29.0 per cent of the weight of the dry saline material, or 22.4 per cent of weight of brine and salt. This would not be sufficient to absorb all of the mother liquors at the final stages of crystallization.

Interpreting the chemical data obtained by the deep bore and the three surface bores, and using the criteria which have been established, I have reached the conclusion below.

The initial stages of Searles Lake were similar to Lake Lahontan. The lake at this period might have been over 1,200 feet in depth, and there is no reason to suppose that it was other than fresh. The drying up of the lake must have extended over a great length of time. The first part of the record, 600 to 627 feet, indicates that the lake had reached saturation and had begun to deposit salines. The brines at this stage deposited salines low in carbonates, high in chlorides and sulphates, and noticeably high in potassium. Either sedimentation proceeded at a rapid rate or crystallization must have been slow. The latter is more likely the case. At a depth of 586 to 596 feet the brine was diluted sufficiently to stop crystallization. The saline content of this brine figures out as follows:

	Per cent.
Potassium chloride	5.48
Sodium chloride	59.15
Sodium sulphate	29.04
Sodium carbonate	1.31
Sodium bicarbonate	2.44

During this stage carbonates were accumulating in the lake waters. Concentration of the water followed and salines were again deposited (575 to 580 feet; samples Nos. 223 and 224). From 427 to 540 feet salines were steadily deposited and inclosed by the sediments. The brine at this stage must have approximated in composition evaporated Owens Lake water, for carbonates are found in increasing amounts. The conditions must have approximated the trona period. During this period the rate of crystallization exceeded sedimentation. The content of potassium is high. From 227 to 427 feet the record is lacking. At 227 feet conditions approaching the sulphate period are indicated. The salines are low in carbonates and high in sulphates and chlorides. Potassium still remains high and amounts to 3.72 per cent of the saline residue (sample 211). From 80 to 227 feet the record is lacking.

The central bore of the Dolbear series indicates that at 65 to 79 feet depth the trona period occurred, followed at 50 to 65 feet by the sodium chloride period, and this was followed by a sulphate period at 35 to 50 feet. An interruption is indicated here. More than likely a humid period diluted the lake and stopped crystallization. From 18 to 35 feet a sulphate period followed, and this in turn was closed by the chloride period. Two periods of desiccation are indicated in the closing stages—the present one and one (recent geologically) at some unknown time before.

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[1] From experiments upon slime cakes formed by vacuum filtration, I have found that the densest portion of a slime cake, formed under a pressure of 11 pounds per square inch, has a specific gravity of 1.84, and a water content of 27.9 per cent. Using these figures and assuming a brine of 1.3 specific gravity and a saline content of 30 per cent by weight would give a saline content for the dried cake of 13 per cent. This figure can be used comparatively with the one obtained by calculation. I am inclined to use the figure obtained by the previous calculation, since the slime experiment does not take into account the time element nor the greater pressures to which mud in the bottom of a lake would be subjected.

The marginal bore also indicates an interruption in the desiccation. A passage from the trona to the sulphate period was followed by a trona period. The last trona period passes gradually into the chloride period, with possible indications of another interruption at 25 to 30 feet depth. More or less sedimentation marked this portion of the deposit. The final capping with a mud layer 13 feet thick closed the cycle of events at this point.

The important question of what became of the residual mother liquor which must have covered the saline bed at the close of the last desiccation period has not been discussed. The suggestion by J. Walther, quoted by Clarke,[1] that residual bitterns might be absorbed by wind-blown sands, and by capillarity brought to the surface, wind eroded, and carried away, occurs as a plausible explanation. Undoubtedly some such action took place locally, but it could not have been on a sufficient scale to account for the removal of all of the mother liquors. The fact that the upper portion of the central bed contains a large proportion of sodium chloride and a brine lower in potassium content than the brine beneath suggests that the closing stages of desiccation must have closely paralleled present conditions in Death Valley. Searles Lake, in passing through the last stages of desiccation, must have deposited sodium chloride, as well as other salts, over a much larger area than that occupied by the present central bed. The shallow lake of mother liquor occupying the central depression must have received periodic accessions of saline material from these marginal deposits. Continued over a long time the effect would be to build up a bed of saline material in which the content of potassium salts would not be conspicuous and which would contain the diluted original mother liquor absorbed in its interstices. Continual accession of salines from the margins would result in a top bed of saline material comparatively poor in potassium salts. This explanation appears to me to be the most reasonable.

The central salt bed over practically the whole area of 12 square miles contains in its interstices a brine which, below the top bed of sodium chloride, is characterized by a relatively high content of potassium. According to Dolbear, the brine containing the high content of potassium salts is confined to a vertical horizon of some 47 feet. Below this horizon the brines contain relatively less potassium salts. The following is an analysis of the rich brine taken from bore hole A7 on the N-S center line and just south of the center of the salt area:

Analysis of brine from Searles Lake, expressed in percentages of the anhydrous residue.

[Sample collected by E. E. Free; analysis by W. H. Ross, of the Bureau of Soils.]

Constituent.	Per cent.	Constituent.	Per cent.	Constituent.	Per cent.
Na	33.57	Mn	None.	I	0.004
K	6.06	Cu	None.	SO_4	12.96
Li	.01	Al_2O_3	.012	CO_3	6.70
Rb	None.	Fe_2O_3	.003	PO_4	.30
Ca	None.	SiO_2	.023	NO_3	None.
NH_4	None.	Cl	37.02	AsO_3	.083
Mg	Trace.	Br	.094	B_4O_7	3.00

This is of the nature of a residual mother liquor. It consists of chlorides in greatest amount, sulphates, carbonates, practically no bicarbonates, and borates. It is conspicuous by the presence of bromine, iodine, and arsenious oxide. The sodium-potassium ratio in this brine is 5.5. The average of 14 of the samples from the deep boring, omitting results upon crystals and Nos. 217 and 215, is 15.5. This would indicate that the water collected in the early stages of Searles was not unlike that of the present lakes in which the sodium-potassium ratio is 20.

Supplementary analyses by A. R. Merz upon samples collected by E. E. Free are given in Table XXIX (Appendix).

The brine body is contained in a mass of coarsely crystalline material, more or less honeycombed. The portion occupying the central mass of salt is richest in potassium salts and borates below the upper salt crust of 18 feet thickness and above the 65-foot level.

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[1] Bul. No. 491, U. S. Geol. Survey, p. 224.

Dolbear[1] presents the following estimate of quantities for the 47-foot bed of brine and crystallized salts:

	Tons.
In brine:	
Potassium chloride	6,455,600
Anhydrous borax	1,900,000
Sodium carbonate	6,630,000
In saline material:	
Potassium chloride	23,900,000
Anhydrous borax	15,200,000
Sodium carbonate	108,500,000
Sodium bicarbonate	42,700,000
Weight of brine	144,000,000
Weight of salts	656,000,000

The figures given are conservative. Dolbear states that the brine contains 4.49 per cent of potassium chloride. The result upon the Bureau of Soils samples is less than this, 3.51 per cent being obtained by their analyses.

Comparison of saline residues.

[Per cent of anhydrous residue.]

	Ca.	Mg.	Na.	K.	Cl.	Br.	I.	SO_4.	CO_3.	PO_4.	AsO_3.	B_4O_7.
Searles	0.0	Trace.	33.57	6.06	37.02	0.094	0.004	12.93	6.70	0.30	0.083	3.00
Death Valley	.002	0.003	36.12	2.63	53.70	......	......	5.62	.18	......	....	Present.
Silver Peak	1,05	.64	35.14	2.94	58.86	......	......	1.26	.30	......	....	Trace.
Owens[1] [2]	.02	.01	38.09	1.62	24.82	......	......	9.93	24.55	.11	.05	.14
Mono[2]	.04	.10	37.93	1.85	23.34	......	......	12.86	23.42	......	....	.32
Great Salt Lake[2]	.33	2.22	33.31	1.92	55.36	......	......	6.53	.07	......	....	....
Pyramid[2]	.25	2.28	33.84	2.11	41.04	......	......	5.25	14.28	......	....	....
Winnemucca[2]	.55	.49	36.68	1.94	47.88	......	......	3.76	7.93	......	....	....
Walker[2]	.90	1.56	34.83	....	23.77	......	......	21.29	17.34	......	....	....

[1] Owens Lake, nitrate=0.45 per cent.
[2] Clarke, Bul. No. 491, U. S. Geol. Survey, pp. 144–146.

Comparison of the saline residues from residual brines, from lake waters in which concentration has proceeded to a considerable extent and from lake waters in which concentration is in initial stages is shown in the accompanying table. Regional differences are, of course, apparent, and must be considered. With the exception of the calcium and magnesium content, the saline residue of the Death Valley brine closely approximates that from Great Salt Lake. Silver Peak is lower in sulphates but more nearly approximates Death Valley. Mono and Owens Lake closely compare and, save for the higher proportion of carbonate, approximate the Searles brine. The residues of Pyramid and Winnemucca are relatively higher in chlorides and lower in sulphates than Mono and Owens. The residue of Walker Lake is high in sulphates and carbonates and lower in chlorides than Pyramid or Winnemucca. Little concentration of potassium is indicated in the last two groups, but decided concentration is shown in the first group, and borates are progressively concentrated from the third to the first group. Nitrate is concentrated from the third to the second group. Great Salt Lake is the only water in the second and third groups in which precipitation of salines is taking place. This residue can be considered intermediate between groups 1 and 2.

COLUMBUS MARSH.

Columbus Marsh is near Coaldale, Esmeralda County, Nev. The area is 32.5 square miles. It receives the drainage of Fish Lake Valley from the south and the basin immediately surrounding the marsh. Two shore lines are present, one about 60 feet above the flat and the other, reported by E. E. Free, at 104 feet. The lake could not have been of much greater extent than the marsh. The comparative shallowness would indicate a relatively small amount of salines. The present surface is a broad plain roughened by very small, more or less rounded, hummocks. There is very little salt in the form of crusts. The surface is dry enough at most times to support a road across the central part. The marsh has some of the characteristics of Rhodes Marsh. No chemical data are available, except those published by the United States Geological Survey in the press bulletin noted below.[1] In this report Gale describes the discovery of a mud at depths from 18 to 38 feet, containing a small percentage of soluble salts, and a high content of potash in the soluble salts. The analyses follow:

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[1] Eng. and Mining Jour. cited before.

Analyses of samples from Columbus Marsh, Nev.

[W. B. Hicks, analyst.]

No. of sample.	Depth.	Total soluble salts.	Percentage of total soluble salts.		
			K.	K_2O.	KCl.
	Feet.	*Per cent.*			
1	1	17.20	1.67	2.01	3.18
2	3	9.07	2.55	3.07	4.85
3	4½	8.88	2.48	2.99	4.73
4	9	10.15	2.95	3.55	5.62
5	12	1.93	(1)	(1)	(1)
6	18	5.17	16.64	20.05	31.72
7	27	6.30	20.90	25.18	39.83
8	30	6.17	13.69	16.49	26.09
9	33–38	6.22	17.12	20.63	32.64

(1) Not determined.

The results are unlike anything as yet reported and their full significance can not be determined without further investigation. The low saline content, 6 per cent, together with the average potassium content, 17.09 per cent (average of results from 18 to 38 feet), would give a potassium content of 1 per cent on the original material dried. The conditions very much suggest that in this occurrence we have a sample of the absorption of a residual mother liquor by wind-blown desert material. It is a matter of doubt whether this mud and brine could be utilized. The removal of a brine from a mud would be attended with greater difficulties than would be the case with the Searles brines. In the latter case the brines are contained in a coarsely crystalline mass and there is comparatively free movement of the brines. In the former case (a more or less compact mud) there would be slow movement of the brines. The most significant thing is not so much the workability of the muds as their high potassium content and the possibility of a larger brine deposit equally rich in potassium at depth. The results of further work in this locality will be awaited with interest. Marsh deposits of borax were worked at Columbus, but at present nothing is being done. These deposits do not show any points of special interest.

DIXIE VALLEY.

Dixie Valley, called Osobb, or Salt Valley, in the Fortieth Parallel Survey Report, lies just east of the Sweetwater range in Churchill County, Nev. It was occupied by a shallow lake which at its maximum covered the present valley to a depth of 150 feet. The Railroad Valley Co. explored this area for potash salts by a number of bores, some extending to 100 feet in depth. The bores showed in the central depression a bed of salt 11 feet thick, mixed with mud, and below this a bed of black mud, 33 feet thick, containing a few crystals of gaylussite. The brine body underlying the salt contains salines composed of 92 per cent sodium chloride, 4 per cent sodium carbonate, and from traces to 0.5 per cent potash. The saline efflorescences consist of sodium carbonate and sulphate, but no potash. The highest content of potash found was 1 per cent of the soluble salts.

Through the courtesy of the Railroad Valley Co. and E. E. Free the results of several bores and the chemical examination of the brines from the bores are presented in the following table:

Record of drill hole No. 1, Dixie Valley.

[Located slightly northeast of the center of sec. 30, T. 23 N., R. 36 E., being the southwest corner of claim No. 42.]

	Feet.
Salt	0 to 1
Black salty mud	1 to 2
Salt with some mud	2 to 3.5

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[1] Press Bul., U. S. Geol. Survey, Feb. 12, 1913.

	Feet.
Black mud with scattered salt crystals	3.5 to 5
Salt	5 to 7
Black mud with scattered salt crystals	7 to 8
Black salty mud, without crystals	8 to 11
Gray clay with occasional layers containing small salt crystals	11 to 15
Black clay	15 to 16
Gray clay	16 to 22
Dry, yellowish clay, occasionally slightly gritty	22 to 26.5
Gray clay	26.5 to 29
Black clay and mud	29 to 33.5
Black mud with many layers containing small crystals of gaylussite	33.5 to 49
Black mud and clay without crystals	49 to 98

Record of drill hole No. 2, Dixie Valley.

[Located slightly southeast of the center of the west line of sec. 19, T. 23 N., R. 36 E., being the northeast corner of claim No. 5.]

	Feet.
Salt	0 to 1
Black mud	1 to 2
Black mud with many salt crystals	2 to 3
Salt	3 to 4.2
Salt with some black mud	4.2 to 6.5
Grayish clay with some salt crystals	6.5 to 8
Yellow clay containing some salt crystals in the upper portions. Lower portions dry and tough	8 to 19
Tough gray clay	19 to 22
Black mud and clay becoming tough and dry in the lower portions	22 to 94.5

Record of drill hole No. 3, Dixie Valley.

[Located slightly northeast of the center of sec. 13, T. 23 N., R. 35 E., being the southwest corner of claim No. 46.]

	Feet.
Salt	0 to 0.25
Black mud	0.25 to 1.2
Salt	1.2 to 2
Black mud	2 to 2.5
Salt with some mud	2.5 to 6
Salt	6 to 6.5
Black mud with salt crystals	6.5 to 10.5
Yellow clay	10.5 to 14.5
Thin layer of salt with some flow of water	14.5 to 14.7
Yellow clay somewhat gritty in upper portion	14.7 to 18
Gray clay	18 to 25
Black mud becoming dry and tough in lower portion	25 to 83

Analyses of brines from drilled holes.

Sample.	Depth.	Conventional combinations, grams per 100 c. c.					Total solids on evaporation, grams per 100 c. c.	K_2O, per cent of total solids.
		NaCl.	Na_2SO_4.	Na_2CO_3.	KCl.	Total by addition.		
Hole No. 1:	*Feet.*							
4	Surface.	27.01	5.02	3.83	0.41	36.27	37.62	0.69
2	4	26.37	4.39	4.12	.46	35.34	38.70	.75
1	26	26.91	4.03	2.65	.19	33.78	35.10	.34
50	64	25.08	4.37	3.30	.28	33.03	32.80	.54
51	71						34.48	.38
52	81						34.64	.42
53	91	23.71	3.73	3.48	.24	31.16	31.57	.48
54	98						31.70	.41
Hole No. 2:								
55	2.5						36.48	.54
56	6.5						35.82	.47
57	10.5						35.63	.43
58	21						35.19	.33
59	28						35.50	.40

Analyses of brines from drilled holes—Continued.

Sample.	Depth.	Conventional combinations, grams per 100 c. c.					Total solids on evaporation, grams per 100 c. c.	K₂O, per cent of total solids.
		NaCl.	Na_2SO_4.	Na_2CO_3.	KCl.	Total by addition.		
Hole No. 2:	*Feet.*							
60	38						33.24	0.33
61	55	28.02	4.69	3.25	0.31	36.27	36.29	.54
62	67						35.66	.50
63	78						36.47	.50
64	85						34.34	.51
65	91.5						36.02	.57
66	94.5	27.79	4.56	3.53	.33	36.21	37.16	.56
Hole No. 3:								
67	1.3						34.99	.28
68	2.5	28.99	3.65	1.77	.15	34.56	34.81	.27
69	5.5						35.00	.27
70	11						35.60	.25
71	14.5						33.92	.25
72	25						35.79	.23
73	35						34.65	.19
74	45	28.42	4.68	2.21	.16	35.47	35.30	.29
75	55						35.77	.35
76	63						35.01	.30
77	71						28.70	.25
Average		26.92	4.34	3.12	.28	34.67	34.96	.40

The section shown by the borings indicates very much the same conditions and history as were described in the Silver Peak Marsh. We have here the case of a shallow lake passing through alternate periods of desiccation. At times desiccation proceeded to such a point as to cause concentration of the lake waters and deposits of salt. More than likely each salt bed was marked by the evaporation of the lake and the formation of a salt playa.

RAILROAD VALLEY.

Railroad Valley is in the northeastern part of Nye County, Nev., about 130 miles northeast of Tonopah and 80 miles southwest of Ely. It is 10 to 20 miles wide from east to west and somewhat over 100 miles long north to south. The flat, central portion of the valley has an area of about 200 square miles. The drainage basin is about 6,000 square miles. Free states that shore-line indications show a lake level varying from 50 to 300 feet above the present bed of the dry lake. A number of playas, covered by thin salt crusts, occupy the bed of the present dry lake. (Plate IV, fig. 2.) Analyses of these crusts and the accompanying brines have been given in a previous section, and many of them show a high potassium content. The Railroad Valley Co. put down a bore 1,204 feet deep on the east-west half-section line of sec. 2, T. 8 N., R. 56 E. The bore is about one-fourth mile west of the west north-south line of sec.1, same T. The log of the bore is herewith presented.

Log of potash drill hole No. 1, Railroad Valley, Nye County, Nev.

[Drilling commenced Mar. 17, 1912; ceased Aug. 27, 1912. All operations in charge of D. H. Walker.]

	Feet.
Mixed clay and sand, mostly sand (fresh water, not artesian)	1– 32
Quicksand (fresh water)	32–103
White clay	103–104
Alternations of quicksand and clay. Some fine gravel among the quicksand (artesian waters in sands, especially at 128 feet)	104–136
Clay	136–178
Very fine quicksand (artesian water, especially at top of division)	178–214
Clay	214–220
Quicksand with fine gravel (artesian water)	220–222
Rapid alternations of sand and brownish clays (artesian water in most of the sands, especially at 250 feet)	222–255
Clay	255–260
Quicksand	260–264

	Feet.
Rapid alternations of sand and brownish clay	264–275
Tough clay	275–285
Sand with coarse and fine gravel, including pebbles ¾ inch in diameter (artesian water)	285–290
Very fine brownish sand	290–305
Tough sticky clay	305–336
Rapid alternations of clay and quicksand, the latter containing a little fine gravel (artesian water)	336–340
Light-colored clay	340–350
Quicksand, probably with occasional thin layers of clay	350–375
Tough gray clay	375–390
Quicksand (small astesian flow)	390–391
Tough gray clay	391–418
Quicksand (small artesian flow)	418–419
Brown clay	419–429
Sand (small artesian flow)	429–430
Hard brown clay with occasional very thin sand streaks	430–445
Gray clay	445–459
Very soft yellowish clay	459–461
Quicksand (artesian water)	461–462
White sticky clay	462–463
Blue-green clay	463–470
Very fine quicksand (artesian water)	470–471
Lead-colored clay	471–478
Very fine sand	478–479
Blue-green clay	479–480
White clay	480–490
Blue-green clay with occasional thin sand streaks	490–493
Gray clay	493–500
Blue-green clay, with occasional thin streaks of coarse sand	500–504
White clay, fragments showing jointed structure	504–511
Tough, blue green clay	511–519
Quicksand (artesian water smelling of sulphuretted hydrogen)	519–520
Gray clay	520–523
Gray clay with occasional thin strata of sand (artesian waters in all sands. Waters smell of sulphuretted hydrogen)	523–529
Gray clay	529–533
Very fine quicksand (artesian water smelling of sulphuretted hydrogen)	533–534
Blue-green clay	534–539
Quicksand with some rather coarse gravel (strong artesian flow. Water carries no sulphuretted hydrogen)	539–541
Sticky yellowish clay	541–549
Tough white clay	549–554
Blue-green clay	554–556
Very tough white clay	556–560
Quicksand	560–561
Blue-green clay	561–583
White clay	583–586
Quicksand (small artesian flow)	586–587
Clay	587–596
Alternations of clay and black sand (small artesian flows in sands, especially at 605 feet)	596–609
Tough white clay	609–620
Gray clay	620–637
Sand	637–638
Very sticky clay	638–655
Light-colored greenish clay	655–657
Very tough white clay	657–676
Quicksand (small artesian flow)	676–677
Rapid alternations of clay and sand (very little water)	677–680
White clay	680–691
Rapid alternations of clay and sand	691–700
Brownish clay	700–719
Sand (very small artesian flow)	719–720
Brownish clay	720–738
Rapid alternations of quicksand and clay, the former carrying a little coarse gravel (small artesian flows)	738–746

	Feet.
Very tough brownish clay	746–759
Rapid alternations of sand with brownish clay (small artesian flows in the sands)	759–771
Hard brownish clay	771–785
Quicksand (artesian water)	785–786
Clay	786–790
Sand (small artesian flow)	790–791
Brownish clay	791–798
Rapid alternations of sand and clay	798–805
Hard brown clay	805–816
Quicksand and gravel (artesian water)	816–822
Hard white clay	822–824
Rapid alternations of brownish quicksands and clays. Some gravel ¾ inch in diameter in the sands (very strong artesian flows in sands. Temperature of water, 22° C.)	824–846
Brownish clay	846–850
Sand and gravel	850–855
Rapid alternations of sand and clay	855–858
Very fine sand	858–862
Rapid alternations of sand and brownish clay	862–865
Gray clay	865–876
Coarse gravel (artesian water)	876–878
Very fine sand	878–882
Rapid alternations of clay and sand	882–886
Gray clay	886–889
Fine quicksand (artesian water)	889–892
Rapid alternations of sand and brownish clay	892–899
Gray clay	899–908
Sand and coarse gravel (very strong artesian flows)	908–910
Very fine sand	910–922
Sand and coarse gravel (small artesian flow)	922–924
Light-gray clay	924–934
Fine sand	934–941
Gray clay	941–945
Sand	945–947
Yellow clay	947–953
Gray clay	953–967
Sand and gravel (small artesian flow)	967–969
Brown clay with occasional very thin streaks of sand	969–980
Brown clay	980–1,002
Fine sand (dry)	1,002–1,003
Hard brown clay	1,003–1,049
Sand (dry)	1,049–1,050
Brown clay	1,050–1,078
Quicksand (probably dry)	1,078–1,079
Brown clay with occasional very thin streaks of sand	1,079–1,085
Tough brown clay	1,085–1,131
Very thin sand streak (dry)	1,131
Brown clay	1,131–1,140
Sand cemented by calcium carbonate, believed to be lake tufa	1,140–1,144
Sticky gray clay	1,144–1,165
Rapid alternations of clay and sand	1,165–1,175
Lime-cemented sand. Probably lake tufa	1,175–1,190
Reddish clay with occasional very thin sand streaks (dry)	1,190–1,204
Fine sand, probably quick	1,204

The casing having stuck hopelessly in the cemented sand between 1,175 and 1,190, it was impossible to carry the hole deeper.

The bore does not show either beds of salines or brines. The material obtained consists of muds, silts, clays, and quicksands. Artesian water was encountered at many points. The nonpenetration of saline beds by a single bore hole is not surprising when one considers the area of the central depression. The fact that artesian flows were encountered would argue that the bore was considerably without the central mud area, or the area of lowest depression. The former lake in evaporating may have separated into several parts, and thus we might have several saline beds of moderate thickness in the central area. The general silting of the whole area would render it extremely difficult to locate these beds. Until proved otherwise by a number of bores, Railroad Valley must be looked upon as a possible source of buried salines. The question as to whether these salines will be characterized by a high potassium content is an open one. The finding of surface crusts and brines of relatively high potassium content proves nothing as far as we know at present about the buried salines and brines. A possible explanation of the high potassium content in the surface salines and brines may be found in the fact that there are a number of hot springs in this area, and these may have been responsible for the surface salines. Until analyses of the waters of these springs are available this is only conjecture.

SAND SPRINGS FLAT.

Sand Springs Flat area is described on the United States Topographic Sheet as "Eightmile Flat" and "Fourmile Flat." It was called "Alkali Valley" in Russell's Monograph on Lahontan Lake. It lies 11 miles southeast of Fallon, in Churchill County, Nev. The area is about 37 square miles. It has a peculiar interest in that a bay of Lake Lahontan once occupied the area. The highest level of Lake Lahontan was 439 feet above the present flat, elevation 3,961. The desiccation of Lake Lahontan would have left a shallow lake upon the flat, and this, on evaporation, would have left a bed of salines. Russell states that the salt bed is from 3 to 5 inches thick near the margin and in the central portion is not less than 3 feet thick. Rain water has collected the salines in the southeast end of the flat. Russell[1] states that after rains a shallow brine lake of several inches depth and about 15 square miles in area occupies this portion. No notable amounts of potassium have been reported from the salines of this area.

SEVIER LAKE.

Sevier Lake is in west-central Utah, Millard County. It is of some interest in that it was formerly a part of Lake Bonneville and for a long time was occupied by a shallow lake, which in recent times has dried up. Gilbert[2] describes the history of this lake. From his account I take the following:

Sections of the saline beds in the central and marginal portions of the dried lake.

Central.	Marginal.
1. Top. Sodium sulphate, 2 inches	1. Top. Sodium chloride crust, ¼ inch.
2. Sodium sulphate with some sodium chloride, 1 inch.	2. Sodium chloride with sodium sulphate and magnesium sulphate—free crystals mingled with water, 1¼ inch.
3. Sodium sulphate, 2 inches	3. Sodium sulphate with sodium chloride, a crust of coherent crystals, ½ inch.
4. Gray clay containing woody fiber, 2 inches	4. Sodium chloride with sodium sulphate; incoherent crystals mingled with water, 1¼ inches.
5. Fine sand containing fresh water shells, 6 inches.	5. Sodium chloride, with sodium sulphate, chemically identical with No. 2, but fine-grained and with the consistence of an ooze; color white above, with occasional passages of pink and green beneath, ½ inch.
6. Gray clay	6. Dark-gray mud, 2 feet.

The analyses upon these from the same reference are given in the succeeding table:

Constituent.	Center.	Margin.	Brine.
	Per cent.	*Per cent.*	*Per cent.*
Sodium sulphate	84.6	14.3	15.5
Sodium carbonate	.4		
Sodium chloride	7.0	80.62	72.1
Calcium sulphate			.5
Magnesium sulphate		5.5	
Magnesium chloride			11.9
Potassium sulphate		.7	
Water		3.6	
Insoluble		.1	
	100.00	100.00	100.00

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[1] Monograph No. 11, U. S. Geol. Survey, p. 235.

[2] Monograph No. 1, U. S. Geol. Survey, p. 244.

The accumulation of sodium sulphate in the center is of interest. The absence of potassium compounds in the brine and the low content in the marginal deposits are conspicuous. The accumulations in Sevier Lake are undoubtedly due to comparative recent action. Deeper bores would have revealed more of the history of the basin and perhaps beds of salines characteristic of the Bonneville period would have been discovered.

BLACK ROCK DESERT, NEVADA.

The Black Rock and Smoke Creek Deserts are of notable extent. The northern extension of Lake Lahontan occupied this area, but no surface deposits of salines have been discovered. Some saline crusts can be found, but these are of little importance. A 500-foot well was put down at Sulphur, on the line of the Western Pacific Railroad and on the edge of the mud flat, but neither oil nor salines were found. West of Gerlach, salt is produced in small quantities by the evaporation of brines obtained from shallow wells.

But few data of a chemical nature are available for this area. In the vicinity of Gerlach samples of mud were obtained from a shallow auger hole. From the same vicinity water samples were also obtained. The analytical results are given below. The muds show a high content of salines, and these consist of chlorides and sulphates, together with small quantities of carbonates. The potassium content is about what would be expected. The mud is a tenacious clay. The waters are somewhat similar in composition to the salines contained in the clays.

Analyses of saline crust and muds from the Black Rock Desert, Nevada.

Sample and depth.	Percentage of total soluble salts.								Total soluble salts.
	Ca.	Mg.	Na.	K.	CO_3.	HCO_3.	SO_4.	Cl.	
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Surface crust	1.56	0.02	34.41	1.12	0.05	0.10	21.36	40.99	59.68
Muds:[1]									
0–1.25 feet	.78	.02	35.90	2.32	.16	.33	6.85	53.63	18.31
1.25–2.5 feet	.71	.03	36.09	2.06	Tr.	.66	7.84	52.57	23.19
2.5–3.75 feet	.63	.02	36.32	2.28	0	.49	4.97	55.37	24.83
3.75–5 feet	.68	.03	36.48	2.33	0	.35	4.07	56.03	34.47

[1] Average ratio Na to K in muds is 16.

Analyses of waters from the Black Rock Desert, Nevada.

Sample.	Percentage of total solids on evaporation.								Solids on evaporation.
	Ca.	Mg.	Na.	K.	CO_3.	HCO_3.	SO_4.	Cl.	
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*Parts per 100,000.*
Water from surface trench	0.48	0.08	36.03	1.49	0.10	0.46	4.64	55.11	5,209
Average, 4 springs	2.11	.06	32.08	2.73	.19	2.97	8.13	47.57	428.4
Boiling hot spring	2.48	Tr.	32.63	2.70	0	1.35	11.25	47.93	444

[Saline clays and crust from point 1.5 miles northeast of Gerlach, Nev. Water from surface trench from same place. Samples by W. S. Palmer; analyses by J. A. Cullen.]

The waters from the four springs averaged were taken 0.25 mile from Gerlach. The temperature of these springs ranged from 16.1° to 32.2° C. Samples by W. S. Palmer; analyses by S. C. Dinsmore.

The boiling spring was three-fourths mile northwest of Gerlach. Sample by W. S. Palmer; analyses by J. A. Cullen.

BURIED DEPOSITS OF SALINES.

The deposits resulting from the desiccation of Searles Lake are exposed on the surface and their discovery was a simple matter. Geological reasoning indicates that the conditions exemplified by Searles must have been repeated at other places in the Great Basin. Evidences of Quaternary lakes are to be found in a number of places, but not in all places do we find the expected saline deposits. The largest Quaternary lake basin, excepting Bonneville, is Lahontan, and it is now occupied by Pyramid, Walker, Humboldt, Carson, and Winnemucca Lakes. Unlike Mono, Owens, and Great Salt Lakes, the waters of these lakes are comparatively fresh. Geological evidence goes to show that Lahontan Basin must have been the locus for an accumulation of salines for a long period. The inconsequential surface accumulations of salines in this basin, coupled with the anomalous condition of the present lakes, led Russell[1] to propose the following hypothesis:

"After the last great rise of Lake Lahontan there was a long-continued episode during which its basin was more arid than at present. Evaporation during that time is thought to have been equal to precipitation, and the residual lakes were reduced to the playa condition—that is, the remnants of the great lake gathered in the lowest depressions of its basin were annually or occasionally evaporated to dryness, and their contained salts were precipitated and either absorbed by the clays, etc., deposited at the same time, or buried beneath such mechanical deposits. This process may be observed in action in many of the valleys of Nevada in which ephemeral lakes occur. The broad naked playas of Black Rock, Smoke Creek, and Carson Deserts, as well as the level floors of the basins occupied by Pyramid, Winnemucca, and Walker Lakes, are in support of this hypothesis. Should the lakes just mentioned be evaporated to dryness, playas would be left similar to those in neighboring valleys of less depth.

"It is beneath the level floors of these valleys and lake basins that the more soluble salts once dissolved in the waters of Lake Lahontan are buried. Borings at certain localities might reveal the presence of strata of various salts, but in most cases they are probably disseminated through great thicknesses of clay, sand, and other mechanical sediments."

Russell's[2] admirable discussion of the freshening of lakes by desiccation, together with the later review in the reference cited above, leaves little to be added. Under the discussion of the present and past rate of accumulation of saline material it was shown that over some 95,000 square miles area a present accumulation of approximately 3,000,000 tons of salines per annum is taking place, and that in the humid period of the Quaternary this rate might have been more than four times as large. No even approximate estimate of Quaternary time for the basin has been made, and consequently no estimate of the probable quantity of salines can be made.[3] That it was large goes without saying. While absolute proof of Russell's hypothesis has not been made, its probability is almost beyond question. If we admit it, the pertinent questions arise: Where are these deposits, and what is their probable value as a source of salines? The answer to the first question has been given by Russell. The answer to the second is given in part by the chemical studies of the deposits in Searles and Columbus Marshes, Death and Dixie Valleys, and the partially concentrated solutions of Mono, Owens, and Great Salt Lakes.

Gilbert shows that Lake Bonneville overflowed and discharged its waters, together with their salines, into river waters which eventually found their way to the ocean. On account of the prevalence of older sedimentaries in the Bonneville basin and the low content of potassium in the brines of Great Salt Lake, together with the above fact, the Bonneville basin is not looked upon as a very favorable place for the discovery of the more valuable salines. On the other hand, Lake Lahontan and the Quaternary basins of the west, central, and southwest parts of the Great Basin have never reached an outlet. The regional rocks are largely volcanic, and consequently these Quaternary areas have been looked upon favorably as a possible source of valuable salines.

If we consider that the present topography of the Lahotan Basin is, in a measure, a counterpart of the topography at the end of the final desiccation period, then we must conclude that the present lakes are holding within their shores the former areas of maximum depression, and, consequently, a part of the saline accumulations is buried in the sediments and beneath the waters of the present lakes. The remainder must be sought for in the mud playas and basins contiguous to the present lake basins.

An examination of Russell's map of Lake Lahontan at its highest water stage[4] indicates a division of the lake into five major lakes, Carson Lake, Black Rock Desert, Pyramid, Winnemucca, Walker, and Honey Lakes, given in the order of their magnitude. Each of these lakes on evaporation must have left deposits of salines. It is not improbable that in some cases several separate deposits were left. The Black Rock Desert is at present a comparatively level plain. As far as known, no notable quantities of salines have been discovered. That they exist in some places beneath the desert sand or absorbed within the muds is probable. The great area of this desert (1,600 square miles approximately within the 4,000-foot contour) and its extreme flatness would render the search for these deposits difficult. Pyramid Lake, the deepest of the present lakes, is 360 feet deep. This basin must have been the deepest of the Quaternary basins. It is an open question whether the waters of Black Rock Desert or those of Carson Lake drained into this basin. Present topographic conditions would indicate no particular drainage from either place. In fact, if we consider that Pyramid Lake receives the largest stream we would conclude that the overflow from this lake during the intermediate stages of evaporation would have been into the Black Rock Desert and into the Carson. Topographic conditions seem to indicate that Walker Lake did not drain in the direction of Carson Lake. The lowest pass between Carson and Pyramid Lakes is at Ragtown, and at an elevation of 4,100 feet. If we assume that the Carson and Truckee Rivers had flows relatively the same as at present, we should expect Pyramid Lake to discharge some of its contents into the Carson. There are no present evidences as to the direction of flow from

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[1] Bul. No. 530 A, U. S. Geol. Survey, p. 16.

[2] 11th Annual Report, U. S. Geol. Survey, p. 244.

[3] Russell estimates the duration of the post-Lahontan period to be less than 300 years. Gilbert estimates that at the present rate of accession some 34,000 years would be necessary to account for the sodium chloride in Great Salt Lake. I have calculated the following: At present rates of accession it would take 18,576 years for the chlorine accumulation in Owens Lake; 9,028 years for the chlorine accumulation in Mono Lake (assuming the same per square mile annual rate of accumulation that was determined for the Truckee Basin); 4,529 years for the chlorine accumulation in Pyramid Lake: 840 years for the chlorine accumulation in Walker Lake, and 6,452 years for the nitrate accumulation in Owens Lake. The impossibility of determining the average rate of accumulation renders such determinations of little value.

[4] Eleventh Annual Report, U. S. Geol. Survey, pl. 5, p. 32, and the U. S. Geol. Survey topographic sheets, Granite Range, Nev.; Disaster, Nev.; and Honey Lake, Cal.

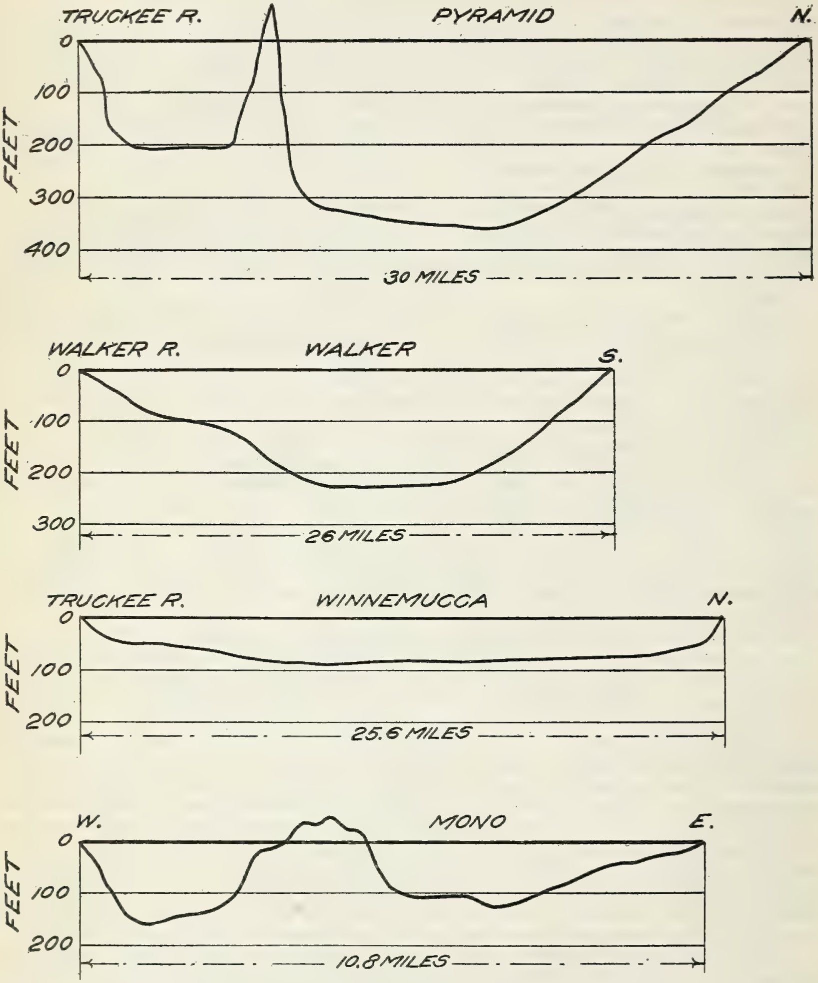

FIG. 7.—Profiles of Pyramid, Winnemucca, Mono, and Walker Lakes.

one lake to the other, and perhaps the assumption that there was no considerable flow from one lake into the other is the nearest to the fact. This would lead us to conclude that in each of these basins we might expect salines at depth.

The present depth of Pyramid and Walker Lakes, needless to say, would preclude exploration work in these localities. The profiles of Pyramid, Winnemucca, Mono, and Walker Lakes are shown in figure 7. These profiles show the deepest portions of the lakes to be in the central part or away from shores or inlet streams. Topographic evidence goes to show that the saline deposits in Black Rock Desert must have been spread over a great area and must have been relatively thin. The difficulty of prospecting or exploring has been commented upon.

Carson Lake is comparatively shallow and would not offer serious obstacles to exploratory work. The fact that the Carson Sink receives the drainage of both the Humboldt and the Carson Rivers, each of which drains relatively large areas, as well as the extent of the Quaternary lake, makes this basin comparatively attractive for exploration. The greater area of the Carson Desert and the difficulty of securing accurate information from surface studies as to the probable structure of this basin would render a search for salines almost as difficult as in the Black Rock Desert.

The U. S. Geological Survey put down a bore in the Carson Desert at what was hypothetically assumed to be the axis of the deepest depression in the Quaternary lake basin. The site of the bore is close to the north end of Timber Lake in sec. 30, T. 21 N., R. 30 E. The bore was sunk to a depth of about 985 feet and failed to penetrate either saline beds or brines. The log of the bore to a depth of 320 feet is published in the bulletin noted below.[1] Sand, clay, and quicksand were the principal sediments penetrated to this depth. Artesian water was encountered at a number of different levels. Examination of these waters showed them to be of low saline content. Certain samples showed from 0.10 to 0.22 per cent potassium.[2] Other water samples showed from traces to 0.1 per cent. At greater depths than that established by the record it is said that no notable quantity of saline material was found. A study of the Carson topographic sheet, together with the information shown by this bore, indicates that the bore was put down in the delta material deposited by the Carson River. That this delta deposit is of great thickness and outside of the area of possible occurrence of saline beds is not an unwarranted conclusion. We would expect sedimentation to be most active at the mouth of the Carson. Examination of older and more recent maps indicates changes in the position of the Carson River where it enters Carson Lake. The delta formed by the Carson during the Quaternary lake period must have been eroded in part and must have supplied the alluvial material of the present delta. The probable changes which took place during the evaporation of Carson Lake in this delta material and in the deeper portions of the basin are represented by figure 8. Three stages are indicated. In the first stage, or the beginning of desiccation, a deep lake is represented, in one end of which is a considerable delta deposit. The finer sediments and silts carried into the lake are represented as a thick bed upon the bottom. As the lake evaporated, erosion began in the former delta deposit and a new delta began to form from the débris of the old. This new delta would be expected to reach out as the lake evaporated and, as it were, push the lake farther and farther down its bed. The end of the desiccation period is represented in the *b* sketch. On the resumption of greater rainfall we would expect silts and sediments to be brought down from the erosion of the remnants of the older delta. Under certain conditions the saline beds would be closed over by this material. The bottom diagram, figure 8, shows the conditions at the end of the third period. An examination of *c* section would indicate that the saline deposits would be removed at some considerable distance from the remnants of the old delta. The flatness of the Carson Desert and its extent, particularly to the east, needs to be seen to be appreciated.

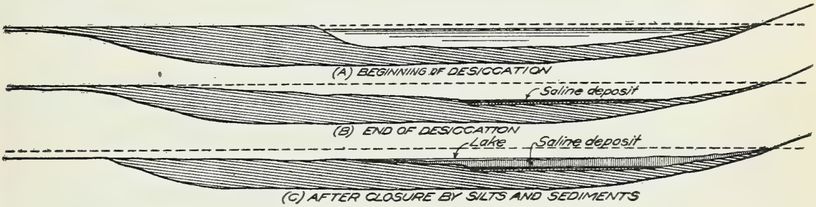
(A) BEGINNING OF DESICCATION
Saline deposit
(B) END OF DESICCATION
Lake
Saline deposit
(C) AFTER CLOSURE BY SILTS AND SEDIMENTS

FIG. 8.—Cross sections showing probable conditions existing in Carson Lake at different stages of desiccation.

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[1] Bul. No. 530A, U. S. Geol. Survey, p. 18.

[2] Probably on total solids.

The shore lines in the bottom of the basin, which appear with great distinctness, indicate the slow recession and evaporation of the waters. Sufficient time is indicated for the development of a structure similar to that shown in sketch *b*. Wind erosion, no doubt, played an important part in the closure of the saline beds. The soft character of the Lahontan sediments and the fact that the prevailing winds are from the west would indicate favorable conditions for æolian action. The east end of the Carson Desert, and particularly that portion along the flanks of the Sweetwater Range, is conspicuous for the large sand dunes which have resulted from the wind action of the present.

The general features involved in the search for the buried salines of the Carson Sink may well be considered. A study of the probable structural relations attending the formation and closure of a saline deposit such as might have taken place in the Carson Sink has shown that the most favorable area is removed from the delta area, either old or new. In the particular case of the Carson Desert a line might be drawn at the present mouth of the Carson and extending southeast and northwest. Southwest of this line is the delta area. Northeast is the area considered as most favorable for the search of a saline deposit. The area between the line established above and the lowest contour—3,900 feet—inclosing the present lake is about 350 square miles. The main deposit of Searles Lake occupies an area having a ratio of 1 to 404, as compared with the area of the whole present basin including the salt deposit. The drainage area of the Carson and Humboldt Rivers is 27,575 square miles. Using the above ratio would give a probable area of saline deposit of 68 square miles. The extent of a saline deposit would be determined by its thickness. Consequently the above area might be larger or smaller. Again, the deposit might be divided, which is not at all unlikely in the present case. The prospecting problem would be to locate by boring an area greater or less than 68 square miles in an area of 350 square miles.

The nature of the saline bed, if it were discovered, might be similar to that in Searles, or the salines might be distributed in a relatively thick bed of æolian sediments. Respecting the probability of potassium little can be said. Gale's discovery in Columbus Marsh opens up possibilities which in my judgment would warrant exploration in this area.

The only other instance of exploration for buried salines is in Railroad Valley, Nev., where a 1,200-foot bore was sunk, but without results. The valley is unlike the Carson Sink in that no large stream discharges into it, and there is no lake of consequence. The results of the bore have been discussed.

SALINES IN PRESENT LAKES.

The composition of the waters of the more important lakes of the basin region are given in Table XV (Appendix). The three most important lakes from the standpoint of concentration and amount of salines are Great Salt, Owens, and Mono Lakes. The computed quantities of the more important salines in these lakes are given in the table which follows:

Quantities of salts in Great Salt, Owens, and Mono Lakes.

Lake.	$NaCl$.	Na_2SO_4.	KCl.	Na_2CO_3.	$Na_2B_4O_7$.
	Tons.	*Tons.*	*Tons.*	*Tons.*	*Tons.*
Great Salt[1]	400,000,000	30,000,000	...	...	...
Owens[2]	20,000,000	22,000,000	2,140,000	22,000,000	...
Mono[2]	86,099,600	47,586,400	10,538,000	92,101,100	945,100

[1] Monograph 1, U. S. Geol. Survey, p. 253.

[2] 8th Annual Report. Quaternary History of Mono Valley, Cal., pp. 295–296. Potassium sulphate has been recalculated to potassium chloride in the case of Owens Lake.

Salt is separated from the brines of Great Salt Lake and at Owens Lake sodium carbonate and bicarbonate have been separated by solar evaporation and crystallization for a number of years. At Large Soda Lake, Nev., soda was also separated. Outside of this, there has been no other commercial utilization of the waters of the basin lakes. Only two other lakes in the basin approach the three mentioned above in degree of salinity—South and Middle Alkali Lakes, Oreg. (Pl. V, fig. 1.) The saline content of the remaining lakes is of little present importance. No important concentration of potassium salts has taken place in the present lakes, excepting inconsequential cases which have been mentioned before. Later investigations have not supported the earlier estimates of notable concentrations of potash salts in Abert Lake and the Surprise Valley. (Pl. V, fig. 2, and Pl. VI.)

CALCAREOUS DEPOSITS ABOUT THE SHORES.

Tufa deposits have been found about the shore lines of many of the Quaternary lake basins. They are not so conspicuous in Bonneville as at Lahontan or Mono. They have been reported from Searles and Owens Lakes. The origin of this tufa, its composition and mineralogy, have been discussed by Russell and Gilbert,[1] and it is not important that they be repeated here. The significant feature of these deposits is their potassium content. Gilbert quotes analyses from the Fortieth Parallel Survey which show 0.22 per cent potassium. This is significant, as it indicates one way in which potassium compounds separate out from lake waters. The deposits are of no commercial interest. They have been an important means of interpreting the events of the Quaternary history.

POTASH-RICH MINERALS.

Of the soluble potash-rich minerals kalinite and niter are the only two known as mineral species in the basin region. Undoubtedly potassium chloride and sulphate are associated with the bedded salines, but no distinct mineral species has been reported.

The insoluble potash minerals, with the exceptions noted below, are associated with other rock-forming minerals in igneous rocks. Rocks containing notable quantities of potash-rich minerals are inconspicuous. Ransome[2] reports a leucite basanite from the Bullfrog district, Nevada, but this rock contains a very low percentage of potash.

The occurrence of alunite has been discussed already. Jarosite contains from 6 to 9 per cent potash. This mineral is not uncommon and has been reported from Tonopah, Goldfield, and Bullfrog, Nev. It is associated with quartz and, in the occurrence at Goldfield, it is found in an altered tuff.[3] It does not occur in quantity and is of no economic importance. Orthoclase has been reported, but, so far as known, no notable amounts of this mineral are available. Adularia has been reported from Jarbridge, Nev. The analyses show a potash content ranging from 11.84 to 15.12 per cent.[4] The mineral occurs associated with quartz in veins. With the exception of the alunite deposit noted in a previous section, the possibility of finding workable deposits of potash-rich minerals or rocks is not good.

GYPSUM.

Three types of gypsum deposits are found in the basin region—rock gypsum, gypsite, and lake gypsum. Rock gypsum occurs in Nevada at Mound House, Gerlach, Lovelock, Table Mountain, the Ludwig mine in Mason Valley, and at Arden, Clark County. At Mound House and Lovelock the gypsum is associated with limestone. At Mound House, Gerlach, and the Ludwig mine the surface gypsum passes into anhydrite at depth. Probably in all cases the rock gypsum is associated with rocks of Triassic age.[5]

At Mound House gypsite occurs in thin beds upon a number of low, crescent-shaped terraces which are a part of the alluvial slope between the rock gypsum deposit and the Carson River. It has undoubtedly been derived from the erosion and partial solution of the rock gypsum deposits above. Seepage and surface waters have caused the concentration of the gypsum in beds varying from 2 to 3 feet in thickness. The material is of a pulverulent nature. Analyses taken from several of these beds and at a number of different points are given in the following table:

Analyses of samples from gypsum deposits.

[Samples collected and analyses made by G. J. Young.]

Constituent.	Sample No.—							
	1	2	3	4	5	6	7	8
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Gypsum	59.79	68.20	79.51	53.94	50.43	82.75	79.81	72.37
Calcium carbonate	14.01	12.83	8.72	12.58	13.58	6.35	8.82	5.21
Insoluble	26.13	8.72	11.78	33.48	35.98	10.80	11.33	22.39

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[1] Monograph 1, p. 167, Gilbert; 11th Annual Report, p. 187, Russell; Bul. No. 108, U. S. Geol. Survey, p. 94, I. C. Russell.

[2] Bul. No. 407, U. S. Geol. Survey, p. 58.

[3] Professional Paper No. 66, U. S. Geol. Survey, p. 108.

[4] Bul. No. 497, U. S. Geol. Survey, p. 52.

[5] See G. D. Louderback, Bul. No. 223, U. S. Geol. Survey, p. 118.

F. L. Hess[1] describes the occurrence of gypsum in recent lake beds in the Mojave Desert, Cal. The beds occur in a periodic lake in the vicinity of Amboy, Cal. Bristol Lake is the name given to the area. The gypsum occurs in the lake bottom close to the shores of the lake. The bed is of variable thickness and its maximum thickness has not been determined. In one place gypsum was found to a depth of 9.5 feet, the upper layers being more or less mixed with dirt. A brine is reached in the lake bed at a depth varying from 8 to 10 feet. Prospect holes show the deposit to be confined from within one-half to 1 mile of the old shore line. The gypsum is of a granular nature. Hess ascribes the localization of a deposit of this kind as being due to the greater evaporation rate of the lake waters near the shore. Capillarity in the marginal material also undoubtedly has contributed to the local concentration of the gypsum.

Rock gypsum is being mined at Mound House, Arden, and Ludwig. The deposits are of considerable commercial importance. The gypsite deposits at Mound House were worked for a time, but have been idle for some years. They are of doubtful value. The gypsum at Bristol Lake is reported by Hess as being exploited by the Pacific Cement Plaster Co.

CONCLUSION.

Repeated reference has been made to the Stassfurt deposits of Germany in connection with the search for potash salts in the United States. While this has served a useful purpose in stimulating the search for salines, it perhaps has resulted in the opinion that similar deposits might be expected in the Great Basin. Such a view can not now be held. The German deposits are in the Triassic and they, as well as the associated sedimentaries, have been folded and tilted. They represent complete desiccation and more or less secondary action before, during, and after tectonic disturbance. Omitting from present consideration the deposits of the Jurassic and Tertiary, the saliniferous deposits of the Great Basin may be said to represent comparatively recent geologic activity. They are confined to the Quaternary lake and desert basins. The older deposits were formed in earlier periods of desiccation, but desiccation did not reach extreme conditions. The present deposits are in process of formation. Very little disturbance of the Quaternary and recent sedimentaries has taken place. More or less secondary action, such as solution, recrystallization, and movement of brines, is taking place. It may be said that the basin deposits already discovered represent the initial stages of what in time might result in deposits rather remotely similar to Stassfurt, but of much less magnitude.

The influence of regional rocks has been commented upon and the prevalence of volcanics in the Great Basin has caused geologists to turn to this region as a place in which to look for potassium salts. Regional differences, caused by the prevalence of different types of rocks, are manifest in the presence of alkali carbonates and borates in the western part of the Great Basin and the presence of chlorides in the eastern portion where sedimentaries predominate. In the case of potassium, no such marked difference is shown. The potassium content in the saline residue of the water of Great Salt Lake is not much less than that of Mono, Owens, and Pyramid Lakes. Humboldt Lake, North, Middle and South Alkali Lakes, it is true, show a higher content of potassium, but these are relatively unimportant. The resistance to weathering of the potash-rich minerals and the ease with which this element is absorbed and removed from surface and underground waters might well account for the low content of potash in all of the lakes.

With the exception of the crusts and efflorescences about hot springs and in soils, no notably high potassium content has been reported from salines taken from beds. The potassium content in material of this nature ranges from less than 1 to 2 per cent. It is not in the salts which have crystallized out, but in the residual brines or mother liquors that concentration of potassium has taken place, and it is to these that we must look for potassium salts. As desiccation approaches completion, so will the residual brines increase in proportion of potassium. A near approach to complete desiccation would give a brine high in potash. The fortuitous absorption and sealing over of such a brine would protect it from further changes, except those produced by circulating underground waters. It is evident that the above action might occur at different stages of desiccation, and brines varying in degree of potash content would be absorbed and sealed in the same way. Sealing would not necessarily have to be caused by the formation of impervious layers, although this would be more effective than a layer of sand. A layer of sand, subsequently flooded with water, would deplete by diffusion the partially concentrated brine beneath and, in time, a much weaker brine would result. It should be noted that the absorption of saline waters which have not reached concentration sufficient to produce crystallization of some of the compounds would give little or no concentration of potassium. The absorption of such a solution by desert sands would give a weak and valueless brine. Doubtless further investigation will show many of the variations indicated above.

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[1] Bul. No. 413, U. S. Geol. Survey, p. 125.

Two general types in the desiccation phenomena may be distinguished, the Searles type, in which a large, deep lake was evaporated, and the comparatively thick body of saline material, restricted in area and saturated with residual brine, was formed; and a second type, which is best illustrated by Death Valley, in which case we have the building up of a mass of muds and silts with interbedded salines, by the repeated formation and desiccation of a shallow lake. To the latter type belong most of the desert, dry lakes, or playas. The line between the two types is not a sharp one.

The possibility of deposits at depth is still not completely disproved. The geological evidence goes to show that several periods of desiccation occurred. Each period might have been characterized by deposits of the kind described above. Such evidence as we have, and it is meager, does not indicate deposits of this nature. The evidence goes to show that the larger Quaternary lakes existed for a long time and desiccation was a feature of their final stages. This would place the period of saline formation at the end rather than at an intermediate time, and would argue for deposits at shallow depths rather than otherwise. On the other hand, the geological evidence is not necessarily complete. The obliteration by erosion of older lake lines than the present ones is not improbable. Only by systematic deep boring could such a question be settled. As the larger Quaternary lake basins are, in almost every instance, occupied by lakes of considerable size and in some instances of considerable depth, the difficulties of such work are apparent.

The question of deep deposits being uncertain, the field becomes narrowed to the deposits which might have resulted from the desiccation periods of the most recent Quaternary lakes. Only in Searles have we surface deposits of this nature. In all other basins, if older deposits than those at present forming exist, they must be sought for at depth. The size of such a deposit would depend upon the area of the drainage basin and the area and depth of the Quaternary lake occupying it. Desert basins showing no signs of former lakes might well be placed in a separate and unimportant class. Such basins can not be said not to have saline beds at depth, but the existence of such beds and their value are doubtful. Upon the criteria stated above I have grouped the desert basins in the following manner:

GROUP I.—*Basins formerly occupied by Quaternary lakes.*

	Square miles.
A. Basins in which the Quaternary lake was over 300 feet in depth: (in order of magnitude on the basis of area):	
Carson and Humboldt	27,575
Black Rock and Smoky Creek Deserts	10,500
Searles (area includes Owens)	4,850
Panamint	1,950
B. Basins in which the Quaternary lake was 300 feet or less in depth:	
Railroad Valley	6,340
Columbus Marsh (including Big Smoky Valley)	5,225
Buena Vista (part of Caron and Humboldt)	4,000
Dixie Valley	2,660
C. Basins which are now occupied by lakes:	
Bonneville Basin	54,000
Walker, Nev	3,850
Alvord, Oreg	3,200
Pyramid, Nev	2,975
Owens, Cal	2,825
Honey Lake, Cal	2,660
Surprise Valley, Cal	2,350
Catlow, Oreg	2,000
Warner, Oreg	2,000
Abert, Chewaucan, and Summer, Oreg	1,500
Madeline Plains, Cal	900
Long Valley, Nev	775
Mono, Cal	770
Silver, Oreg	500
D. Doubtful basins:	
Diamond Valley, Nev.	
Danby and Bristol Lakes, Cal.	
Franklin and Ruby Lakes, Nev.	

GROUP II.—*Basins in which there are no evidences of Quaternary lakes.*

	Square miles.
A. Death Valley, includes Amargosa drainage and basin	23,160
B. Silver Peak	550
Rhodes Marsh	540
Teels	320
All other basins in which the playa contains notable quantities of brine and in which the brines are close to, or at, the surface.	
C. All other desert basins and playas not included in the above groups.	

The order given in each main group is the order of relative importance. In each subgroup the order given is the order of areal importance. Groups A and B of each main group are believed to be the most favorable areas for exploration work. Group II is of very much less importance than Group I.

Of the basins enumerated above, Searles is the only one in which the investigation has shown sufficient concentration of potassium salts in the residual brines to be of probable commercial importance. The salines associated with the potassium salts and the possibility of producing several products predict success in the exploitation of this area. The chemical problem of separating the several salines is a difficult one, and upon its solution hinges the success of the enterprise. The presence of brines of moderate concentration is shown in Death Valley and Silver Peak.[1] It is a matter of some doubt whether these brines can be worked. The investigation of the Carson Sink, Railroad Valley, and Columbus Marsh is inconclusive. Until the possibilities of the areas considered most favorable have been exhaustively studied, it is inadvisable to attempt exploration of the other areas.

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[1] The potassium in the surface brines of the smooth salt area of Death Valley is equivalent to 1.72 per cent potassium chloride; in the brines from the Survey's bores in Death Valley it is equivalent to 0.94 per cent and in the brines of Silver Peak Marsh 1.50 per cent. But comparatively little concentration would be required in these brines to produce a brine of the same content of potassium chloride as the Searles brine. The Death Valley surface brine would have to be concentrated one-half, the deeper brines one-fourth, and the Silver Peak brine somewhat less than one-half. In Death Valley the summer evaporation rate for a brine is said to be from 24 to 30 inches per month. The cost of evaporating a brine under such conditions would be almost nothing. The amount of brine available for pumping and the practicability of constructing vats upon the smooth salt area would have to be determined by detailed examination and experimentation. In my opinion the experiment of producing potassium salts by evaporating the Death Valley brine is well worth carrying out, presupposing that the detailed examination shows a sufficient quantity of brine.

APPENDIX.

MINERALOGY OF THE SALINES.

A number of minerals have been reported in the salines of the basin. In addition to distinct mineral species mention must be made of the mixtures of chlorides, sulphates, borates, and carbonates which are of common occurrence.

List of minerals.

[Compiled from Dana, Clark, Eakle, and records of Cooperative Laboratory and State Mining Laboratory of the University of Nevada.]

Name.	Chemical symbol.	Name.	Chemical symbol.
Soluble minerals:		Insoluble or almost insoluble minerals:	
Thermonatrite	$Na_2CO_3.H_2O$.		
Natron	$Na_2CO_3.10H_2O$.	Anhydrite	$CaSO_4$.
Trona	$Na_2CO_3.NaHCO_3.2H_2O$.	Gypsum	$CaSO_4.2H_2O$.
Mirabilite	$Na_2SO_4.10H_2O$.	Celestite	$SrSO_4$.
Thenardite	Na_2SO_4.	Calcite	$CaCO_3$.
Halite	$NaCl$.	Dolomite	$MgCa(CO_3)_2$.
Borax	$Na_2B_4O_7.10H_2O$.	Tychite	$2MgCO_3.2Na_2CO_3.Na_2SO$.
Soda niter	$NaNO_3$.	Colemanite Pandermite (var.).	$Ca_2B_6O_{11}.5H_2O$.
Niter	KNO_3.		
Nitrocalcite	$Ca(NO_3)_2.nH_2O$.	Ulexite	$NaCaB_5O_9.8H_2O$.
Nitromagnesite	$Mg(NO_3)_2.nH_2O$.	Howlite	$H_5Ca_2B_5SiO_{14}$.
Hanksite	$Na_{22}K(SO_4)_9(CO_3)_2Cl$.	Boracite (?)	$Mg_7Cl_2B_{16}O_{30}$.
Kalinite	$K_2SO_4.Al_2(SO_4)_3.24H_2O$.	Neocolmanite	Same composition as colemanite.
Partly or slightly soluble minerals:		Sulphur	S.
Glauberite	$Na_2SO_4.CaSO_4$.	Pirssonite	$Na_2Ca(CO_3)_2.2H_2O$.
Sulphohalite	$3Na_2SO_4.2NaCl$.		
Gaylussite	$Na_2Ca(CO_3)_2.5H_2O$.		
Northupite	$MgCO_3.Na_2CO_3.NaCl$.		

In addition to the above, potassium chloride and sulphate, and magnesium chloride and sulphate, are to be found in mixtures but have not been reported as minerals. Hydrogen sulphide, ammonia, iodine, bromine, and arsenious oxide have been reported in analyses. Marsh gas has been reported from a bore near Fallon, Nev.

Certain temperature observations have been made in connection with the synthetic studies of saline compounds and these have been summarized below:

Temperature controlling formation of saline minerals.

°C.	
110	Pandermite formed from solution of sodium and potassium chlorides.[1]
100	Anhydrite formed from action of sulphuric acid on calcium carbonate. Tychite and northupite formed at temperature of steam bath.[2]
70	Colemanite formed from ulexite in salt solution.[1]
34 and above	Thenardite formed from sodium sulphate solution.[3]
34 and below	Mirabilite formed from sodium sulphate solution.[3]
20 to 38	Trona, borax, ulexite, gaylussite, natron, gypsum, hanksite, halite, sulphohalite; deposited from solution. Anhydrite forms from saturated salt solution.
10 and above	Glauberite.[1]

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[1] Clarke, Bul. No. 491, Data of Geochemistry, U. S. Geol. Survey, p. 216.

[2] Am. Jour. of Sci., 4th Series, v. 20, p. 217.

[3] The Occurrence of Potassium Salts in the Salines of the United States, Bul. No. 94, Bureau of Soils, U. S. Department of Agriculture.

Soluble minerals are deposited from solution by simple evaporation. The presence of one or more soluble minerals in an evaporating solution would result in the partial separation of a mixture of the several compounds present, and the proportion of each in the "solid phase" would depend upon the solubility and proportion of each originally present. Under certain conditions, as, for instance, the preponderance of one compound, when the solution reached a concentration exceeding the solubility of this compound, it would separate out alone until the residual solution reached a constant condition, when another compound or compounds would separate out of the "constant solution." The evaporation of a solution containing a number of soluble salines might be expected to deposit, in sequence, first a single compound and then always a mixture of compounds, the sequential mixtures varying with the composition of the original solution. Just what mixture would be deposited would depend upon the composition of the "constant solution" formed at the several stages. Turrentine [1] has very fully discussed van't Hoff's work upon the separation of saline compounds from solution, and it is unnecessary to repeat it here.

Experimental data for the interpretation of results which might be expected from the evaporation of saline solutions occurring in the western half of the Great Basin are not complete. Chatard published the results of his work upon the saline solutions of Owens and Mono Lakes, and these have been presented in another place. They indicate, for a system composed of chlorides, sulphates, carbonates, and borates, the initial separation of calcium carbonate and ferric oxide, followed in order by trona and then mixtures of carbonates, chlorides, and sulphates. The last brine contained sodium carbonate, sodium chloride, potassium chloride, sodium borate, and nitrates. Apparent separation of potassium chloride or sodium borate in the first crops of crystals was due to the inclosure of the brine by the separated salts. The nonseparation of potassium and boron compounds was due to the small proportion of these compounds originally present. The carrying of Chatard's experiments several steps further would have undoubtedly resulted in additional crops of crystals, which would have contained potassium and boron compounds.

Instances of the deposition of soluble minerals by evaporation of solutions are, of course, common. Halite, trona, mirabilite, natron, and hanksite are deposited from lake waters. Of the soluble minerals named, with the exception of mirabilite, as far as our present information goes, none would be affected by the climatic temperature range. Mirabilite alters to thenardite at ordinary temperatures and when in solution thenardite is deposited at a temperature of 34° C., or above. This temperature is not uncommon in the Great Basin.

Of the partly soluble and almost insoluble minerals our information concerning temperature conditions of formation is scanty. Most of them are formed by direct precipitation under normal temperature conditions. Pandermite, colemanite, tychite, and northupite would appear to require higher temperatures than would be afforded by the climatic temperature range. The absence of colemanite in most marsh deposits (reported only in Searles Marsh), and its presence in veins and as amygdaloids in basalt, would favor the supposition that this mineral only formed in the presence of heated solutions. Tychite and northupite are comparatively rare, and we might well conclude that some local conditions—such as the presence of a hot spring—favored their formation. The occurrence of howlite in association with colemanite would lead to the supposition that this mineral forms under similar temperature conditions.[2]

Secondary changes in deposited salines have not been made the subject of special study. Examples of the reduction of sulphates by organic matter and the formation of hydrogen sulphide and sulphur; the reduction of nitrates and the formation of ammonia have been reported. Reactions of this kind are characteristic of the more deeply buried beds. The formation of ulexite in nodules in the marshes would indicate this mineral to be of secondary nature. Anhydrite slowly changes over into gypsum. Mirabilite alters to thenardite. Glauberite alters to calcite (Dana). Ulexite alters to gypsum (Dana).

Minerals typically occurring in veins and veinlets are kalinite, alunite, niter, nitrocalcite, nitromagnesite, colemanite, and howlite. All others occur in playa beds, in crusts and efflorescences. Glauberite has been found associated with thenardite and mirabilite. Sulphohalite has been found implanted on crystals of hanksite (Dana). Hanksite is found with halite, thenardite, glauberite, trona, and borax. It has also been found inclosed in borax crystals (Dana).

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[1] Bul. No. 94, Bureau of Soils. The Occurrence of Potassium Salts in the Salines of the United States.

[2] Bul. Dept. of Geology, University of California, vol. 6, No. 9, p. 187.

TABLES.

TABLE I.—*Showing mean annual precipitation.*

BASIN REGION—UTAH.

Station.	Altitude.	Mean annual precipitation.	Station.	Altitude.	Mean annual precipitation.
	Feet.	*Inches.*		*Feet.*	*Inches.*
Ibapah	7,500	12.37	Alpine	4,900	19.28
Frisco	7,318	8.21	Toole	4,900	16.22
Woodruff	6,500	10.01	Blackrock	4,872	10.61
Meadowville	6,200	18.41	Mount Nebo	4,650	10.53
Marysville	6,180	12.23	Deseret	4,541	8.04
Beaver	6,000	12.87	Provo	4,532	13.71
Heber	5,606	17.64	Logan	4,507	15.69
Nanti	5,575	12.06	Salt Lake City	4,366	16.33
Modena	5,479	11.50	Ogden	4,310	14.74
Richfield	5,350	7.96	Farmington	4,267	21.17
Government Creek	5,277	14.38	Corinne	4,240	12.51
Scipio	5,260	15.25	Kelton	4,230	6.38
Fillmore	5,100	14.72	Coyoto	....	8.21
Minersville	5,070	11.54	Garrison	....	6.83
Levan	5,010	16.38			
Promontory	4,913	8.23	Average	....	12.80

BASIN REGION—NEVADA (AND PORTION OF CALIFORNIA).

Station.	Altitude.	Mean annual precipitation.	Station.	Altitude.	Mean annual precipitation.
Bodie, Cal	8,248	14.48	Quinn River Ranch	4,850	6.55
Belmont	8,000	8.67	Battle Mountain	4,843	6.71
Hamilton	7,977	16.80	McAfee's Ranch	4,835	5.46
Summit, Cal	7,017	47.78	Gardnerville	4,830	12.12
Potts	6,990	7.14	Palisade	4,821	8.69
Austin	6,594	11.72	McDermott	4,700	11.94
Eureka	6,500	13.17	Golconda	4,697	5.96
Palmetto	6,500	18.53	Beowawe	4,695	6.48
Tybo	6,500	9.32	Carson	4,660	11.01
Lewer's Ranch	6,282	26.96	Hawthorne	4,569	3.56
Candelaria	6,180	4.98	Reno	4,497	8.65
Fenelon	6,128	9.23	Mill City	4,391	4.73
Pioche	6,100	11.24	Iron Point	4,375	7.45
Tonopah	6,090	6.37	Winnemucca	4,344	8.65
Clover Valley	6,000	15.00	Humboldt	4,336	5.32
Ruby Valley	6,000	10.71	Fernley	4,150	4.62
Toana	5,975	8.16	Hot Springs	4,072	3.37
Truckee	5,818	26.90	Lovelock	3,977	3.10
Halleck	5,631	8.29	Fallon	3,965	4.81
Wells	5,628	8.97	Brown	3,929	3.83
Boca	5,535	20.34	Downeyville	3,800	6.47
Crane's Ranch	5,350	11.48	Las Vegas	2,033	3.57
Elko	5,342	8.44	Logan	1,700	6.04
Carlin	5,232	7.22			
Verdi	4,895	15.47	Average	....	10.34

BASIN REGION—CALIFORNIA.

Station.	Altitude.	Mean annual precipitation.	Station.	Altitude.	Mean annual precipitation.
Bishop	4,450	5.96	Barstow	2,150	3.61
Independence	3,907	5.25	Bagdad	784	2.98
Lone Pine	3,661	5.28	Needles	477	4.30
Keeler	3,620	3.06			
Mohave	2,751	5.00	Average	....	4.43

BASIN REGION—OREGON.

Station.	Altitude.	Mean annual precipitation.	Station.	Altitude.	Mean annual precipitation.
Lakeview	4,825	17.85	Klamath Agency	4,200	21.47
Silver Lake	4,700	10.40	Burns	4,157	10.87
Warner	4,700	14.80	Riverside	3,000	9.76
Paisley	4,500	10.90			
Klamath Falls	4,250	12.54	Average	....	13.59
Happy Valley	4,200	13.73			

TABLE II.—*Mean annual precipitation at certain stations in the Great Basin, arranged according to latitude.*

North latitude 42° to 43°.			North latitude 39° to 40°.			North latitude 37° to 38°.			North latitude 35° to 37°.		
Station.	Elevation.	Mean annual precipitation.	Station.	Elevation.	Mean annual precipitation.	Station.	Elevation.	Mean annual precipitation.	Station.	Elevation.	Mean annual precipitation.
	Feet.	*Inches.*		*Feet.*	*Inches.*		*Feet.*	*Inches.*		*Feet.*	*Inches.*
Grants Pass	956	32.20	Sacramento	71	19.50	Merced Falls	173	23.21	Independence	3,907	5.25
Ashland	1,940	20.18	Rocklin	249	28.45	Summerdale	2,270	56.45	Lone Pine	3,661	5.28
Klamath Falls	4,250	12.54	Auburn	1,363	34.93	Bishop	4,450	5.96	Keeler	3,620	3.06
Lakeview	4,825	17.18	Colfax	2,421	49.01	McAfee's Ranch	4,835	5.46	Mohave	2,751	5.00
Warner	4,700	14.80	Gold Run	3,222	54.49	Palmetto	6,500	18.53	Barstow	2,150	3.61
Happy Valley	4,200	13.73	Blue Canyon	4,695	72.82	Pioche	6,100	11.24	Bagdad	2,150	2.98
			Cisco	5,939	51.96	St. George	2,880	8.66	Needles	477	4.30
			Summit	7,017	48.00	Kanab	4,925	14.02			
			Truckee	5,820	27.65	Aneth	4,800	7.16			
			Boca	5,531	20.47						
			Reno	4,497	8.65						
			Wadsworth	4,084	4.59						
			Fallon	3,965	4.81						
			Austin	6,594	11.72						
			Eureka	6,500	13.17						
			Ely	6,421	12.24						
			Garrison	4,850	6.83						
			Deseret	4,541	8.04						
			Scipio	5,260	15.25						
			Castle Dale	5,500	8.52						
			Green River	4,080	6.38						
			Cisco	4,447	5.94						

NOTE.—Weather stations are arranged from west to east with exception of stations in north latitude 35° to 37°. Stations below horizontal lines are in Great Basin and stations above these lines are on contiguous watershed. Stations in north latitude 35° to 37° are in Great Basin, with exception of Needles.

TABLE III.—*Statistics of temperature.*

	Mean temperature.	Mean maximum.[1]	Mean minimum.[2]	Range maximum to minimum.	Mean relative humidity.
	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*
Western Utah	47.4	103.6	−18.2	121.8	52
Nevada	47.2	105.8	−17.4	113.2	51.3
Oregon	46.8	106.1	−22	128.1	[3] 61
California	63.8	112.5	10	102.5	[4] 36

[1] Highest annual temperature of each station.
[2] Lowest annual temperature of each station.
[3] Baker City, Oreg.
[4] Independence, Cal.

TABLE IV.—*Proportional area of mountains, outwash slopes, silt, playa, and water in the Great Basin region.*

	Sierraville, 1,344 square miles.	Reno, 972 square miles.	Wadsworth, 1,344 square miles.	Carson, 3,780 square miles.	Amargosa, 8,307 square miles.	Owens Valley,[1] 3,300 square miles.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Mountains	75.4	76	61.4	41.3	55.3	35
Outwash slopes				13.7	24.5	46
Silt	23.7	18.2	32.4	35.5	18.2	14
Playa		.6	.4	5.1	1.7	5
Water	.8	5.2	5.6	4.3	0	

[1] Water-Supply Paper No. 294, U. S. Geol. Survey.

TABLE V.—*Run-off of the basin region.*[1]

River.	Drainage area.	Mean annual run-off.	Run-off per square mile.	Depth on drainage area.	Length of record.[1]
Western Utah:	*Sq. miles.*	*Second-feet.*	*Second-feet.*	*Inches.*	*Years.*
Weber River		586			2
Bear River	6,000	1,860	0.308	4.19	9
Logan River	218	339	1.56	21.18	6
Spanish Fork	670	157	.234	3.18	4
Sevier River	3,990	208	.052	.70	5
Provo River	640	433	.676	9.16	6
Nevada:					
Carson	988	454	.461	6.25	6
Truckee	1,520	1,030	.677	9.18	6
East Fork Walker	1,100	213	.193	2.63	3
Humboldt at Oreana	13,800	261	.019	.25	7
Humboldt at Palisade	5,010	448	.089	1.23	4
California:					
Owens River		281			
Mojave River at Victorville	400	78.1	.195	2.65	5
Susan River at Susanville	256	151.9	.591		2

[1] Water-Supply Papers, Great Basin region.

TABLE VI.—*Run-off of the basin region.*

TRUCKEE.

Year.	Tahoe (519 square miles).		State line (955 square miles).		Vista (1,519 square miles).		Derby (1,740 square miles).		Pyramid (2,130 square miles).	
	Run-off.	Run-off per mile.	Run-off.	Run-off per mile.	Run-off.	Run-off per mile.	Run-off.	Run-off per mile.	Run-off.	Run-off per mile.
	Sec.-ft.	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*	*Sec.-ft.*
1903	205	0.40	753	0.79	786	0.52			859	0.40
1906	589	1.14	1,420	1.48	1,610	1.06				
1908							626			
1909	488	.92	1,530	1.60			1,550	0.892		

HUMBOLDT.

Year.	Elko (1,150 square miles).		Golconda (10,800 square miles).		Oreana (13,800 square miles).	
	Run-off.	Run-off per mile.	Run-off.	Run-off per mile.	Run-off.	Run-off per mile.
	Sec.-feet.	*Sec.-feet.*	*Sec.-feet.*	*Sec.-feet.*	*Sec.-feet.*	*Sec.-feet.*
1903			171	0.0158	121	0.009
1906	210	0.183	373	.034	303	.022
1907	248		998		720	
1908	103		239		164	
1909			235	.03	287	.021

WALKER.

Year.	Coleville (306 square miles).		Yerington (1,100 square miles).		Wabuska (2,420 square miles).	
	Run-off.	Run-off per mile.	Run-off.	Run-off per mile.	Run-off.	Run-off per mile.
	Sec.-feet.	*Sec.-feet.*	*Sec.-feet.*	*Sec.-feet.*	*Sec.-feet.*	*Sec.-feet.*
1903					170	0.0704
1906	582	1.90	322	0.293		
1907			390			

CARSON.

Year.	Woodfords (70 square miles).		Empire (988 square miles).		Hazen.	
	Run-off.	Run-off per mile.	Run-off.	Run-off per mile.	Run-off.	Run-off per mile.
	Sec.-feet.	*Sec.-feet.*	*Sec.-feet.*	*Sec.-feet.*	*Sec.-feet.*	*Sec.-feet.*
1903			429	0.43		
1906	231	3.30	798	.807		
1908			212			
1909			678	.686	645	

TABLE VII.—*Run-off in the Oregon Lake region.*[1]

	Area of watershed.	Mean flow.	Flow per square mile.
	Sq. miles.	*Sec.-feet.*	*Sec.-feet.*
Malheur Lake	865	364	0.37
Harney Lake, Silver Creek (Riley)		116	
Silver Lake Basin	221	55.2	.25
Abert Lake Basin		189	.694

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[1] Water-Supply Paper No. 212, U. S. Geol. Survey.

TABLE VIII.—*List of lakes, with elevations and drainage area of the basins.*

Lake.	Basin area.	Lake area.	Ratio basin to lake.	Elevation.	Depth.
	Sq. miles.	*Sq. miles.*		*Feet.*	
Great Salt Lake (including Utah and Sevier Lake).	52,000	2,498	20.8	4,200	49 feet average.
Franklin Ruby Eagle	[1] 1,200	105	11.4	5,950	
Pyramid	[1] 2,975	310	9.6	3,880	361 deepest.
Winnemucca				3,875	87 deepest.
Humboldt	[1] 27,575	195	141.4	3,929	
North Carson				3,900	Variable.
South Carson				3,916	4 feet, very shallow.
Walker	[1] 3,850	118	32.6	4,083	118 feet average.
Mono	[1] 770	85.5	9.0	6,426	61.5 average.
Tahoe	519	111	4.6	6,225	1,635 deepest.
Owens	[2] 3,300	100	33	3,569	40 average.
Honey Eagle	[1] 2,660	111.6	23.8	3,949	18 inches.
Malheur Harney	700	125.6	5.5	4,088	10 feet.
Alvord	[1] 3,200	4.9	653	4,200	Very shallow.
Silver	500	15	33.3	4,340	
Warner	2,000	81	24.6	4,600	
Abert	900	60	15	4,400	None exceed 25 feet.
Summer	550	60	9.1	4,300	
Goose	1,065	190	5.6	4,800	
Surprise Valley	[1] 2,350	137	17.1	4,640	

	Square miles.
Total lake surface	4,196
Basin area	210,000
Ratio	50 to 1

[1] Free's table of basin areas.

[2] Water Supply Paper No. 294, U. S. Geol. Survey.

TABLE IX.—*Distribution of different rocks in Great Basin region.*

Map V, Clarence King, fortieth parallel (17,612 square miles).

	Square miles.		Per cent.
Quartz Porphyry Granite	1,512.9	Alluvial and sediment	67.0
Diorite Diabase Syenite	103.9	Basalt Andesite Diorite	14.2
Trachyte Andesite Prophylite	336.6	Rhyolite Granite	18.8
Ryolite	1,810.0		
Basalt	2,005.8		
Carboniferous and Archean	561.0		
Triassic			
Tertiary, Humboldt and Truckee			
Quaternary and Recent			
Lake			

Truckee folio (910 square miles).

	Square miles.		Per cent.
Granodiorite	180	Granodiorite and rhyolite	22
Diabase Porphyrite Augite Porphyry	18	Basalt Andesite Diabase	45.1
Gabbro	6	Metamorphic	6.15
Rhyolite	20	Sediment	14.3
Andesite	332	Water	12.5
Basalt	54		
Slate Chert Quartzite Metamorphic	4		
Juratrias Shist slate	52		
Neocene lake beds	5		
Pleistocene	125		
Water	114		

	Per cent.
Maps IV and V, King (35,200 square miles):	
Granite	10
Rhyolite and trachyte	23
Basalt and andesite	14
Alluvial and sediment	53
Southwestern Nevada and eastern California (8,685 square miles):	
Alluvial	54.9
Limestone	12.1
Andesites and basalts	11.5
Rhyolites and granites	21.5

TABLE X.—*Composition of rocks of basin region.*[1]

Constituent.	Granite (av. of 113 analyses).	Rhyolite (av. of 103 analyses).	Andesite (av. of 131 analyses).	Dacite (av. of 44 analyses).	Diorite (av. of 85 analyses).	Diabase (av. of 19 analyses).	Basalt (av. of 110 analyses).	Sandstone (av. of 55 analyses).	Limestone (av. of 29 analyses).	Shales (av. of 16 analyses).
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
SiO_2	66.64	71.55	61.29	65.31	58.84	52.04	51.29	70.55	8.82	54.32
Al_2O_3	14.76	13.90	15.16	15.37	16.06	15.89	15.65	5.80	.89	14.54
Fe_2O_3	1.62	1.20	2.71	2.45	1.97	2.48	3.10	1.06		2.23
FeO	1.72	.94	2.86	1.13	3.79	6.84	5.98	2.53	1.01	2.81
MgO	1.51	.60	2.99	1.34	3.93	5.95	8.37	1.16	3.58	3.18
CaO	2.74	1.56	4.84	3.35	6.27	8.43	8.78	5.33	44.35	4.47
Na_2O	3.48	3.23	3.30	3.55	3.62	3.20	2.81	1.82	.51	1.65
K_2O	4.04	4.17	2.93	2.85	2.17	.98	1.26	1.32		2.11
H_2O-	.38	.52	.63	1.18	.25	.47	.74	2.96	1.17	1.74
H_2O+	1.11	1.71	1.42	2.29	1.31	2.17	1.78			3.44
TiO_2	.42	.30	.56	.53	.67	1.06	1.01	.39	....	.62
ZrO_2	.03	.03	.02	.01	.01	.00	.01	....	....	....
P_2O_5	.16	.13	.26	.15	.22	.23	.37	.17	.13	.17
BaO	.12	.09	.15	.09	.08	.16	.08	....	....	.08
SrO	.04	.03	.05	.04	.03	.01	.04	....	....	....
MnO	.05	.04	.09	.05	.08	.09	.11	....	1.14	.37
S	.74	....	.07	.02	.16	....	.08	....	....	....
Cl	.03	....	.08	.18	.03	....	.05	....	....	....
F	.02	....	....	Tr.	....	....	....	....	....	....
CO_2	.32	....	.56	.07	.51	....	.49	6.74	38.40	7.93
Li_2O	Tr.	....	Tr.	.04	....	....	....	....	....	....
SO_3	.07	....	.03	(?)	....	....	....	.17	....	.34
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

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[1] Compiled from: Vol. I, Fortieth Parallel Survey, Bul. No. 419, U. S. Geol. Survey; Monographs I and XI, U. S. Geol. Survey; Bul. No. 491, Data of Geol. Chemistry, U. S. Geol. Survey.

TABLE XI.—*Analyses of well and spring waters.*

[Parts per 1,000,000. Analyses by S. C. Dinsmore.]

Reference No.	Locality.	Remarks.	Total solids.	SiO_2.	Fe_2O_3 and Al_2O_3.	CaO.	MgO.	SO_3.	K_2O.	Na_2O.	Cl.	Free ammonia.	Albuminoid ammonia.	HCO_3.	H_2SO_4.
Dinsmore:															
1243	Battle Mountain	Well	4,422.2	53.4	16.1	60.3	11.7	39.1	17.8	1,858.0	490	....	....	....	....
1258	Yerington	Spring	872.257	101.2	6.1	68.0	.467	513.5	17.23	114.49	51.0	0.194	0.076	....	....
1257	Moana	Well	424.854	81.2	2.2	31.3	1.6	211.05	17.6	50.18	29.0	.004	.020	....	....
1260	Mount Peavine	Spring	1,200.778	38.4	4.0	283.1	2.26	649.50	Tr.	17.42	6.0	.056	.042	....	....
1261	Freys	Well	1,088.636	120.3	5.9	48.5	1.08	445.8	2.21	408.7	56.0	.136	.01	....	....
1262	Sparks	do	1,339.609	104.7	32.2	36.1	1.709	753.4	16.7	353.8	41.0	....	....	....	....
1265	Reno	Artesian well	157.72	54.5	4.3	28.7	6.32	13.02	10.28	37.60	3.0	....	....	....	....
1270	Tonopah	Water supply	5,789.905	42.0	268.8	833.2	1,151.38	2,679.37	44.05	889.15	77.0	1.24	.14	....	....
1271	Goldfield	Well water	642.70	53.2	10.8	34.4	5.84	97.50	31.01	361.95	48.0	....	....	....	....
1272	do	do	602.37	54.6	12.8	27.0	5.14	91.70	33.33	323.80	54.0	....	....	....	....
1273	do	Water supply	822.364	54.4	4.4	146.4	28.20	145.5	12.15	228.11	202.0	.024	.03	....	....
1274	do	do	347.527	34.6	3.5	55.0	1.10	47.3	16.85	127.75	60.00	Tr.	.027	....	....
1280	Reno	Well	3,221.91	33.6	11.10	541.2	119.3	1,106.74	14.01	1,359.96	36.00	....	....	....	....
1285	Fallon	Well water	762.54	67.1	Tr.	7.0	None.	....	24.64	571.62	119.50	1.10	Excessive.	....	44.68
1302	Rawhide	Crystal Wells water supply.	2,663.555	58.1	4.8	33.2	2.17	333.94	9.73	1,855.99	180.00	.120	.045	184.71	....
1302	do	Spring 0.25 mile from Crystal Wells.	2,183.65	70.2	2.4	56.0	2.61	375.92	9.74	1,293.46	191.50	....	....	181.68	....
1302	do	Crystal Rock water	2,727.46	62.2	3.8	35.4	3.33	331.68	11.22	1,932.87	177.40	....	....	169.56	....
1302	do	White Rock well water.	2,620.40	68.10	3.2	151.4	46.39	342.24	10.71	1.744.16	128.00	....	....	130.20	....
1319	Sparks	Spring	849.02	95.0	Tr.	31.9	8.69	4.28	48.90	625.25	35.00	....	....	....	....
1328	Fallon	Well	1,108.17	49.0	6.0	5.54	6.08	3.97	22.06	846.52	169.0	....	....	....	....
1331	Rawhide	Town supply	1,014.80	37.1	8.25	65.25	10.87	331.41	26.92	369.66	165.34	....	....	....	....
1332	Dixie	Well	1,608.69	24.9	8.50	393.35	77.87	640.53	13.67	232.37	217.50	....	....	....	....
1334	Madeline Valley	do	452.90	57.50	5.50	92.25	59.70	19.51	15.85	100.59	102.00	....	....	....	....
1342	Elko	do	489.73	44.2	2.7	76.8	16.27	165.10	7.27	127.89	49.50	....	....	....	....
1344	Plumas Junction	Spring	111.90	32.4	Tr.	33.6	17.6	Tr.	1.5	20.8	6.0	....	....	....	....
1350	Reno	Well	413.74	32.4	....	....	....	....	....	12.50	....	....	....	225.55	....
1351	Goldfield	do	456.62	43.7	....	....	....	....	....	76.00	....	....	....	....	....
1359	Hawthorne	do	825.41	52.1	4.5	198.0	18.81	190.87	25.44	323.19	12.50	....	....	....	....

TABLE XII.—*Analyses of waters from Amargosa Valley.*

[Parts per 100,000. Analyses by J. A. Cullen.]

No. of sample.	Total solids.	Ca.	Mg.	K.	Na.	Cl.	SO_4.	CO_3.	HCO_3.
237	105.6	6.9	6.0	5.8	10.4	8.5	27.9	1.2	22.0
238	1,692.2	Tr.	.7	44.8	534.4	285.0	544.3	96.0	155.6
284	101.6	6.7	3.0	4.3	18.3	17.0	30.7	1.12	20.7
295	49.8	10.2	10.8	12.8	132.1	101.3	160.8	4.8	65.9
296	93.2	5.1	3.3	3.9	17.0	8.5	30.0	2.4	25.6

237. Water Willow Creek at railroad bridge south of Morrison's.
238. Water Amargosa River, same locality.
284. Shoshone, Cal. Water from warm spring.
295. Well at Fairbank's house, Shoshone.
296. Water spring in railroad cut south of Tecopa, Cal.

TABLE XIII.—*Analyses of water from Furnace Creek and Death Valley.*

[Parts per 100,000. Analyses by J. A. Cullen.]

No. of sample.	Total solids.	Ca.	Mg.	K.	Na.	SO_4.	Cl.	CO_3.	HCO_3.
305	64.8	2.4	1.4	1.0	14.5	14.2	10.6	2.4	14.6
307	20,360.0	175.0	50.3	152.7	7,500.0	874.0	11,525.0	Tr.	11.0
325	490.4	71.4	37.0	5.6	75.6	173.0	147.7	Tr.	17.8
348	65.2	4.8	3.0	1.5	7.7	19.2	4.9	Tr.	20.0
349	1,141.6	3.6	3.3	9.0	321.1	646.0	29.6	Tr.	19.5

305. Slough at first crossing, road from Furnace Creek to Bennett's Well. Water from surface.
307. Water from hole 18 inches deep 1 mile north of sink (saline pond northeast of Bennett's Well).
325. Water from main water hole at Bennett's Well.
348. Water from Texas Spring, Furnace Creek Ranch.
349. Water from well in Furnace Creek Canyon, 13.5 miles east of Furnace Creek Ranch.

NOTE.—A trace of borax is found in all samples.

TABLE XIV.—*Analyses of soluble salts contained in soils.*

Location and No. of sample.	Total soluble salts.	Percentage of total soluble salts.									
		Ca.	Mg.	Na.	K.	SO_4.	Cl.	HCO_3.	CO_3.	NO_3.	PO_4.
Fallon, Nev., alkali soil:[1]	*Per ct.*										
Crust No. 9	4.10	0.88	Tr.	30.66	1.51	56.98	5.52	4.45	0.35	......	......
First foot, No. 10	3.57	.78	Tr.	31.20	1.62	49.72	10.64	6.09	.35	......	......
Second foot, No. 11	3.33	.66	Tr.	30.85	1.62	51.44	8.07	7.36	......	......	......
Third foot, No. 12	1.70	Tr.	Tr.	29.76	3.65	41.65	8.23	15.65	1.06	......	......
Fourth foot, No. 13	.93	Tr.	Tr.	27.68	6.22	38.85	9.01	18.24	......	......	......
Fifth foot, No. 14	.78	Tr.	Tr.	28.73	4.61	37.18	10.00	19.48	......	......	......
Average	2.40	.38	Tr.	29.81	3.20	45.97	8.58	11.88	.23	......	......
Fallon soil	1.34	.76	0.04	32.36	.30	56.23	9.53	.76	.02	......	......
	.89	......	......	31.70	2.10	34.08	12.24	16.71	3.16	......	......
	1.18	......	......	32.43	1.27	42.82	12.76	10.22	.50	......	......
	1.18	......	.18	31.83	1.13	44.07	10.27	11.96	.56	......	......
	1.41	......	......	32.04	1.07	48.55	8.05	9.55	.74	......	......
	1.81	.94	......	31.42	1.28	54.73	8.33	3.30	......	......	......
	1.54	1.80	......	27.47	5.05	53.20	8.51	3.97	......	......	......
	.24	......	......	32.22	3.77	25.94	10.46	15.06	12.55	......	......
	1.01	......	......	27.74	7.54	37.26	13.56	10.45	.97	2.48	Tr.
	1.60	......	......	28.28	6.46	45.95	10.27	6.96	......	2.08	Tr.
	.44	......	......	31.30	2.12	15.38	6.63	39.79	4.78	......	......
	.51	......	......	33.70	2.01	19.64	9.38	19.20	16.07	......	......
	1.94	......	......	30.73	4.31	35.11	12.41	12.88	4.56	......	......
	.66	......	......	29.85	3.58	32.08	8.71	22.71	3.07	......	......
	1.65	......	......	32.23	.84	40.42	10.09	14.95	1.47	Tr.	......
	1.80	......	.66	30.87	1.50	50.20	8.85	7.53	.39	......	Tr.
	.49	......	......	29.84	3.10	18.28	4.05	36.04	8.59	......	Tr.
	.80	......	......	30.24	2.43	38.95	5.99	20.68	1.71	......	Tr.

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[1] Records of Bureau of Soils.

TABLE XIV.—*Analyses of soluble salts contained in soils*—Continued.

Location and No. of sample.	Total soluble salts.	Percentage of total soluble salts.									
		Ca.	Mg.	Na.	K.	SO_4.	Cl.	HCO_3.	CO_3.	NO_3.	PO_4.
	Per ct.										
Fallon soil	3.11	0.53	......	31.92	1.18	52.59	10.30	3.48	......	......	Tr.
	.63	......	......	30.98	3.08	26.08	16.85	20.84	2.17	......	Tr.
	1.08	......	......	32.73	2.15	30.47	21.68	11.69	1.29	......	Tr.
	1.76	......	0.38	33.06	1.03	39.91	19.41	5.45	.77	......	Tr.
Average	1.23	.2	.68	31.1	2.60	38.27	10.83	13.82	2.90	......	......
Swan Track, Utah:[1]											
No. 7246	2.46	.81	.48	31.61	3.64	19.56	36.66	4.39	2.85	......	......
No. 7247	2.28	1.05	.61	33.26	2.80	17.06	39.40	2.76	3.06	......	......
No. 7250	.43	3.23	3.23	21.29	5.55	20.39	13.43	22.23	10.65	......	......
No. 7254	2.05	.68	.58	33.59	2.72	16.27	40.42	3.50	2.24	......	......
No. 7257	1.86	1.07	.32	32.12	3.76	17.40	37.71	6.44	1.18	......	......
No. 7260	.56	.71	.71	29.14	5.76	8.63	25.19	21.59	8.27	......	......
No. 7262	.65	.92	.92	27.69	6.46	14.16	22.46	20.32	7.07	......	......
No. 7269	2.24	10.72	1.43	18.40	3.30	27.86	26.51	10.80	.98	......	......
No. 7275	1.35	6.23	.89	23.14	2.22	20.18	13.50	28.65	5.19	......	......
No. 7279	2.70	.21	.21	34.41	2.62	20.31	38.46	2.47	1.31	......	......
No. 7271	2.04	8.32	.48	22.53	2.64	26.36	22.04	15.38	2.25	......	......
No. 1000*a*	.45	7.96	3.54	14.16	6.63	29.65	12.39	22.13	3.54	......	......
No. 1001*a*	.56	2.48	2.12	23.05	5.32	30.50	17.38	19.15	......	......	......
No. 1002*a*	.80	1.49	1.49	26.98	3.71	26.73	21.78	17.82	......	......	......
No. 1003*a*	.80	1.21	1.21	27.18	4.06	24.96	21.30	20.08	......	......	......
Bear River Valley, Utah:[1] No. 11456	.41	7.84	2.45	17.16	3.92	12.26	22.54	33.83	......	......	......
Utah:											
No. 13955	.43	5.07	6.46	13.37	5.53	10.14	25.80	33.63	......	......	......
No. 13706	.68	4.67	4.67	17.78	7.58	6.70	41.10	17.50	......	......	......
No. 13705	14.9	9.48	2.65	23.74	.70	6.05	56.74	.64	......	Tr.	Tr.
No. 1130*a*	.36	11.66	5.56	9.44	6.67	Tr.	41.67	25.00	......	......	......
Elsmore, Utah,[1] Redfield clay, No. 4729	1.72	4.42	1.28	24.65	3.37	44.42	15.58	5.23	1.05	......	......
Salt Lake City,[1] soil No. 1061*a*	2.10	Tr.	Tr.	35.38	2.09	14.04	42.79	5.70	......	......	......
Cornine, Utah,[1] No. 1129*a*	.68	8.14	4.07	17.72	4.07	10.75	43.03	12.22	......	......	......
Salt Lake City,[1] soil	1.23	1.14	Tr.	34.37	2.51	12.31	46.27	3.40	......	......	......
Silver Lake, Oreg.,[1] No. 1059*a*	1.3	......	......	24.23	12.56	29.84	14.47	16.54	2.36	......	......
Average	1.8	3.98	1.81	24.65	4.40	18.66	29.54	14.8	2.08	......	......
Harney County, Oreg.,[2] soils:											
0–1 foot	.566	5.05	1.30	......	25.44	10.67	21.2	17.6	.84	......	......
1–2 feet	1.049	.27	......	......	16.8	4.14	52.4	12.3	2.05	......	......
2–3 feet	.734	.69	......	......	50.00	13.1	19.75	8.44	8.03	......	......
3–4 feet	.662	.45	......	......	45.3	4.23	18.1	15.1	16.7	......	......
4–5 feet	.938	8.20	.32	......	27.8	7.14	10.3	2.53	13.8	......	......
5–6 feet	.864	......	......	......	32.6	5.55	9.72	12.7	9.23	......	......
2 miles north of Lawen:[2]											
0–1 foot	.202	7.42	......	......	27.2	27.2	4.95	28.2	......	......	......
1–2 feet	.126	19.0	3.97	......	23.0	8.73	4.76	31.7	......	......	......
2–3 feet	.114	26.3	4.38	......	23.6	8.77	5.26	31.5	......	......	......
3–4 feet	.140	12.8	4.28	......	20.7	7.14	7.14	29.2	......	......	......
4–5 feet	.128	13.2	3.90	......	26.6	8.59	6.25	29.6	......	......	......
5–6 feet	.194	8.24	......	......	28.4	8.76	10.3	29.3	......	......	......
Lake County, Oreg.,[3] soils:											
1. Thousand Spring Valley	......	......	......	33.81	......	35.62	16.21	14.26	1.00	......	......
2. 3 miles west Christmas Lake	......	......	......	33.00	......	39.13	6.37	26.75	......	......	......
3. ½ mile south Christmas Lake	......	......	......	34.12	......	48.15	15.93	1.80	......	......	......
4. Well No. 21	......	......	......	32.49	......	27.84	7.12	38.44	......	......	......
5. North end of sink of Peter Creek	......	......	......	31.32	......	26.29	10.08	32.27	......	......	......
6. 1 mile south of Fossil Lake	......	......	......	33.09	......	57.16	7.38	23.6	......	......	......
7. ½ mile east of Cliff post office	......	......	......	19.61	......	......	6.72	40.34	......	......	......
8. Center of north alkali flat	......	......	......	20.14	......	......	15.13	27.23	......	......	......
9. Western arm of alkali basin	......	......	......	55.62	......	......	20.17	24.20	......	......	......

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[1] Records of Bureau of Soils.
[2] Water-Supply Paper No. 231, p. 53.
[3] Water-Supply Paper No. 220, p. 72.

TABLE XV.—*Analyses of river and lake waters of the Great Basin region.*

Rivers and lakes.	Cl.	SO₄.	CO₃.	PO₄.	NO₃.	B₄O₇.	Na.	K.	Ca.	Mg.	Al₂O₃.	Fe₂O₃.	SiO₂.	Solids on evaporation.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Parts per 100,000.*
Rivers:														
Truckee	7.59	12.87	33.30	......	......	......	17.26		11.02	3.49	14.47			15.3
Walker	7.50	16.14	30.34	......	......	......	18.07		12.96	2.21	12.78			18.0
City Creek	5.38	2.87	52.57	......	......	......	3.74		24.19	7.15	.41		3.69	24.3
Humboldt	2.19	13.92	39.55	......	......	......	13.63	2.92	14.28	3.62	.38	......	9.51	36.1
Ogden	23.21	5.65	33.68	......	......	......	11.31	4.16	16.05	5.94	......	......	......	44.4
Weber	13.73	9.25	40.00	......	......	......	8.37	4.19	18.19	6.27	......	......	......	45.5
Bear	32.36	8.16	21.53	......	......	......	20.54		10.12	4.76	2.53		......	63.7
Jordan	34.76	30.68	Tr.	......	......	......	23.04		10.26	1.26	......	......	......	109.0
Lakes:														
Tahoe	3.18	7.47	38.73	......	......	......	10.10	4.56	12.86	4.15	......	......	18.95	7.3
Humboldt	31.82	3.27	21.57	.07	......	......	29.97	6.54	1.35	1.88	......	......	3.53	92.9
Utah	26.87	30.14	8.48	......	......	......	18.34	1.75	5.34	6.85	......	......	2.23	125.4
Tulare	17.38	16.91	26.55	......	......	......	33.51	1.82	1.50	1.78	......	......	.55	136.0
Walker	23.77	21.29	17.34	......	......	......	34.83		.90	1.56	......	......	.31	250.0
Pyramid	41.04	5.25	14.28	......	......	......	33.84	2.11	.25	2.28	......	......	.95	348.6
Winnemucca	47.88	3.76	7.93	......	......	......	36.68	1.94	.55	.49	......	......	.77	360.2
Tulare	20.26	20.77	19.55	......	......	......	35.79	2.44	.28	.26	......	......	.65	491.0
Harney	27.50	7.67	25.87	......	......	.92	35.78	1.91	......	.07	......	......	.28	1,047.7
Black	7.68	13.24	37.73	Tr.	......	Tr.	39.05	2.03	......	......	......	......	.27	1,850.0
Abert	36.04	1.90	20.67	......	......	......	39.33	1.44	......	......	......	......	.62	3,917.2
Mono	23.34	12.86	23.42	......	......	.32	37.93	1.85	.04	.10	Tr.	Tr.	.14	5,117.0
Owens	25.67	9.95	23.51	......	......	.48	37.83	2.18	.02	.01	.04	.02	.29	7,270.0
Sevier	52.66	10.88	......	......	......	......	33.33	......	.12	3.01	......	......	......	8,640.0
(?)	36.51	10.36	13.78	......	......	.25	36.63	2.01	.22	......	......	......	.24	11,370.0
Large Soda	55.69	6.52	......	......	......	......	32.93	1.70	1.05	2.10	.01			23,036.0
Great Salt	24.82	9.93	24.55	.11	.45	.14	38.12	1.62	.02	.01	.04		.14	21,370.0
Owens	25.39	7.62	26.06	.27	Tr.	Tr.	37.42	1.74	1.47	.03	......	......	......	1,590.0
Summer	13.96	17.70	27.79	Tr.	Tr.	Tr.	36.19	1.77	2.16	.43	......	......	......	600.0
Fossil	34.84	5.62	18.73	.41	Tr.	Tr.	37.48	1.60	1.22	.10	......	......	......	2,010.0
Christmas	17.36	13.29	28.78	Tr.	Tr.	Tr.	32.00	5.18	2.04	1.35	......	......	......	470.0
North Alkali	26.85	10.61	21.49	.17	Tr.	Tr.	36.51	4.24	.11	.02	......	......	......	9,510.0
Middle Alkali	12.50	34.12	15.22	.28	Tr.	Tr.	34.12	3.72	.01	.03	......	......	......	14,610.0
South Alkali	42.94	2.73	13.56	.28	......	......	38.64	1.66	.08	.11	......	......	......	3,690.0

NOTE.—Analyses from Bul. No. 491, U. S. Geological Survey, pp. 144–151, excepting last seven, which were performed by J. G. Smith, Bureau of Soils, on samples collected by E. E. Free.

TABLE XVI.—*Quantity of saline material carried annually by certain rivers of the Great Basin.*

Constituent.	Owens.[1]	Owens.[2]	Humboldt.	Truckee.	Walker.	Bear River, Utah.
	Tons.	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*
SiO_2	9,460	12,967	8,818	22,432	4,827	....
Fe	47.3	66.3	....			....
Ca	3,547	9,348	13,246	17,053	4,890	127,391
Mg	1,017	3,618	3,343	5,379	818	59,938
Na-K	9,460	20,807	15,355	26,797	6,822	258,634
HCO_3	26,253	63,628	36,781	51,767	11,544	343,833
SO_4	7,095	16,284	12,911	19,895	6,087	102,647
NO_3	284	512	....	....	....	....
Cl	4,020	9,951	2,032	11,774	2,833	407,473
Total solids	44,701	102,228	92,851	155,335	37,783	1,259,235
Discharged into	Owens Lake.	Owens Lake.	Humboldt Lake.	Pyramid Lake.	Walker Lake.	Great Salt Lake.
Total solids, parts per million.	189	339	361	153	180	687
Mean annual flow, second-feet	240	306	261	1,030	213	1,860

[1] Owens River at Round Valley.

[2] Owens River at Charlie's Butte.

TABLE XVII.—*Yield of salines per square mile of watershed per year.*

Constituent.	Truckee.[1]	Walker.[1]	Humboldt.[2]	Owens.	Tuolumne.	Yuba.	Kern.	San Luis Rey.	San Ysabel Creek.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
SiO_2	29,524	6,972	128	16,200	54,822	113,580	301,970	17,368	244,006
Fe			48	82	947	1,703	2,516	67	942
Ca	22,443	7,063	1,919	11,680	49,838	105,475	301,970	23,532	160,855
Mg	7,080	1,182	484	4,560	21,431	34,887	70,461	7,284	72,108
Na	35,267	9,852	1,834	26,000	54,822	70,750	340,400	22,244	23,296
K			391		5,482	10,385	28,688	2,409	
CO_3	67,998	16,552	5,319	....	....	....	....	....	7,210
HCO_3	....	....	....	79,400	204,340	389,436	1,191,130	91,333	887,500
SO_4	26,183	8,591	1,871	20,200	59,807	105,475	352,307	29,696	166,407
NO_3	....	....	....	640	....	....	....	....	4,659
Cl	15,497	4,092	294	12,440	32.893	44,623	152,660	21,852	210,781
Total solids	203,992	54,304	11,288	127,600	368,800	681,516	2,130,600	179,850	1,442,166
Suspended matter	....	....	....	....	338,906	1,549,640	2,734,560	79,563	....
Area, square miles	1,520	1,100	13,800	1,600	1,500	1,220	2,345	318	128
Rainfall	....	....	....	....	15 in. +	15 in. +	15 in. +	Less than 15 in.	Less than 15 in.
Mean annual flow, second-feet.	1,030	213	261	306	3,793	5,023	1,996	90.4	45.35
Second-feet per square mile.	0.677	0.193	0.019	0.191	2.52	3.56	0.83	0.284	0.355
Pounds per square mile per second-feet per annum.	301.908	280,751	593,748	633,520	146,746	191,717	2,565,954	633,274	4,062,411

[1] Bul. No. 491, Data of Geochemistry, p. 147.

[2] Ibid., p. 148.

TABLE XVIII.—*Analyses of alkali crusts.*[1]

Description of sample.	Total soluble salts.	Percentage of total soluble salts.										
		Ca.	Mg.	Na.	K.	SO_4.	Cl.	HCO_3.	CO_3.	NO_3.	PO_4.	B_4O_7.
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Alkali crust, Geary tract, Huntington, Utah, No. 1005a	43.2	1.39	5.40	22.08	0.35	69.00	1.38	0.40	....	....	....	....
Goshen Valley, Provo, Utah, No. 794a	21.62	2.96	.97	32.44	2.71	1.18	59.25	.44	0.05	....	....	....
Provo, Utah, No. 793	11.03	.34	.30	36.26	1.25	3.55	21.70	15.16	21.44	....	....	....
Sanchez, Provo, Utah, No. 7	6.09	.52	.72	33.52	2.52	12.22	9.23	16.68	24.59	....	....	....
Sanchez, Provo, Utah, No. 6	2.15	1.48	2.70	24.98	3.16	45.91	6.51	10.98	4.23	....	....	....
South end Sevier Valley, Utah, from nook along river, No. 4725	36.99	.05	Trace.	36.82	1.10	15.85	44.72	.65	.81	....	....	....
Black alkali crust, Sevier Valley, Utah, No. 4724	5.04	1.55	.32	31.28	2.86	17.68	33.46	12.49	.36	....	....	....
White alkali crust, Sevier Valley, Utah, No. 4723	3.03	5.55	Trace.	24.58	3.24	35.02	8.13	18.17	5.28	....	....	....
White alkali crust, Sevier Valley, Utah, No. 4722	5.27	2.62	.42	27.88	1.44	54.20	2.66	8.96	1.82	....	....	....
South end Sevier Valley, Utah, No. 4721	2.01	3.98	.60	22.97	6.36	12.23	23.76	30.11	....	....	....	....
Alkali crust from hot spring, Monroe, Sevier, Utah, No. 4718	37.33	1.78	.48	30.04	1.88	50.91	14.33	.19	.39	....	....	....
White alkali crust, Richfield, Utah, No. 4718	21.51	2.19	6.28	22.94	.34	38.91	28.74	.56	....	....	....	....
White alkali crust from Richfield, Utah, along roadside, No. 4717	24.87	1.74	6.26	22.71	.41	44.81	22.86	1.21	....	....	....	....
East of Joseph, Sevier County, Utah, near springs south end Sevier Valley	18.36	3.08	.18	31.34	1.40	32.23	31.25	.39	.03	....	....	....
Narrows, Oreg., No. 350a	85.24	.08	.10	41.61	.43	3.38	.39	3.19	50.82	....	....	....
Truckee-Carson Project, Fallon, Nev	100.0	.93	.50	39.46	.30	37.61	16.95	3.07	1.18	....	....	....
Salt crust from south of Upper Surprise Lake, No. 95	31.03	.26	.26	39.60	2.80	10.35	34.94	.10	11.69	Trace.	Trace.	Trace.
Salt crust from Salton Sea, near Montmere, No. 106	40.57	3.65	1.02	30.21	.04	34.58	30.27	.23	Trace.	Trace.	Trace.	Trace.
Salt crust from Salton Beach, near Travertine rock, No. 113	53.99	2.96	.72	28.38	.24	61.75	5.10	.85	Trace.	Trace.	Trace.	Trace.
Salt crust from Imperial Junction Beach, No. 130	14.26	8.70	.56	25.55	.91	26.60	37.26	.42	Trace.	Trace.	Trace.	Trace.
Averages	28.17	2.29	1.38	30.23	1.68	30.39	21.64	6.22	6.13	....	....	....

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[1] Records of the Bureau of Soils.

TABLE XIX.—*Analyses of salt and water samples taken in Railroad Valley, Nev.*

[Analyses by A. R. Merz.]

No.	Description.	Total salts per 100 c. c.	Potash in total salts.
		Grams.	*Per cent.*
17	....	0.04	....
18	Water from ditch in Hot Creek Canyon, 0.5 mile below source, Wager Ranch	.06	....
21	Water from spring in Rattlesnake Canyon	.04	....
23	Water from stream in Tybo Canyon at junction of canyon, 0.75 mile above store	.03	....
25	Water from draw about 3 miles east of Warm Springs, Hot Creek Valley	.0680	....
26	Salt crust at edge of this draw	2.07	5.25
27	Water from south ditch at west end of Twin Springs Pass	.0368	....
28	Salt from flat south of this ditch	13.16	4.25
29	Water from north ditch; same locality	.08	....
30	Salt crust from north side of this ditch	6.22	6.52
31	Water from spring at house in Twin Springs Pass	.03	....
34	Water from stream at east end of Twin Springs Pass	....	....
39	....	.0676	....
40	Salt crust from edge of this stream	1.74	....
42	Water from Mormon Well	.0256	....
43	Surface salt crust here	4.55	5.29
45	Salt crust from seepage below terrace at Sharps' Ranch	27.36	5.05
47	Water from main spring, Sharps' Ranch	.0352	....
48	Salt crust from flat near this spring	33.98	3.10
49	Water from well at Sharps	.04	....
50	Water from Willow Spring	.05	....
51	Standing water from outflow of Willow Spring onto flat	.18	....
52	Water from Bullwhacker Springs	.0372	....
53	Outflow from Bullwhacker Springs onto flat	.3352	....
54	Salt from playa below Willow Springs, 1 mile northwest	25.24	.89
55	On same playa, 0.5 mile north of No. 54	22.74	3.28
56	Edge of main flat below Bullwhacker Springs	53.80	1.22
57	Salt from main flat, 0.25 mile west of No. 56	7.58	1.64
58	Salt crust from outflow flat of Willow Springs	33	5.87
59	Salt crust from surface near Bacon Springs	27.56	4.10
61	Water from Cold Spring, 1 mile north of Horton's Ranch	.0376	....
62	Salt crust from surface near this spring	24.48	4.68
63	Water from draw 2 miles out of Allred, on Duckwater Road	.03	....
64	Salt crust from soil surface in Duckwater Hills, 0.5 mile east of Duckwater	27.56	1.05
65	Water from ditch at Irwin Ranch	.0428	....
66	Salt crust from near ditch here	12.10	1.65
70	Water from main spring at Lockes	.04	....
71	Salt crust from surface near this spring	59.92	4.35
73	Water from spring on spring deposit well, 6 miles south of Lockes	.07	....
75	Salt crust from near this spring	1.59	....
76	Same, 100 yards southeast	4.55	8.53
80	Salt crust from draw, log 38 miles out of Lockes on road to R. R. V. Co. camp, east ditch of this draw	68.22	6.85
81	Same draw. Salt from ridge between ditches	56.63	2.98
82	Same draw. Salt from west ditch	55.72	3.67
84	Salt from surface in dune lands, log 55, out of Lockes to camp	14.69	4.06
87	Salt near road, log 60	30.46	4.53
88	Salt near road, log 6.5	24.03	2.33
89	First pan crossed by road. Salt just west of west edge, near road	25.58	5.71
90	Same pan, just east of west edge, near road	49.48	7.91
91	Same pan, salt from center 200 feet south of road	70.97	6.97
92	Same pan, center, 200 feet north of road	74.72	8.46
93	Same pan, just west of east edge, near road	56.37	7.54
94	Same pan, just east of east edge, near road	16.68	3.98
95	Salt from small draw at log 7.1, west edge	53	7.39
96	Same draw, east edge	71.64	9.20
97	....	69.12	7.72
98	....	55.16	9.22
99	Small draw at log 7.2, west side	64.96	8.52
100	Same draw as No. 99, main drainage line	66.62	5.76
101	From large pan on drainage line, the west side of which is at log 7.3, west edge just north of road	34.48	2.22
102	Same pan, one-third across from west side north of road	55.18	8.96
103	Same pan, just north of road at culvert	43.24	3.90
104	Same pan, extreme east edge, log 7.4	53.96	3.78
105	West edge of a drainage line just at head of salt flat (to south), log 7.7, north of road	72.64	6.38
106	Same, 100 feet east of No. 105	46.38	6.73
107	Same, 80 feet east of No. 106	76.38	5.00
108	Same, at culvert, 80 feet east of No. 107	60.02	3.41
109	Same, 110 feet east of No. 108	58.72	2.38
110	Same, extreme eastern edge, 125 feet east of No. 109	28.54	3.99

TABLE XIX.—*Analyses of salt and water samples taken in Railroad Valley, Nev.*—Con.

No.	Description.	Total salts per 100 c. c.	Potash in total salts.
		Grams.	*Per cent.*
111	First salty drainage line west of R. R. V. Co. camp, about 60 feet from west edge and 20 feet north of road	59.62	6.11
112	Same, main drainage line, 125 feet east of No. 111 and 125 feet north of road	59.16	5.45
113	Same, extreme eastern edge, 100 feet east of No. 112 (75 feet north of road)	56.48	6.20
114	Small salt spot 420 feet east of No. 113 and 30 feet south of road	72.22	4.23
115	Surface salt at northeast end of salt flat, north of spring deposit hills, 6 miles south of Locke's Ranch	41.24	1.53
116	Same, about 0.25 mile southwest of No. 115	10.56	6.02
120	Salt from seepage on north side of southern of these hills	5.36	6.16
122	Salt from below spring on this latter hill	79.56	12.10
124	Main flat near camp. Salt from 97 feet west of southwest corner of Locke's claim	68.74	1.90
125	Same, 375 feet west of southwest corner Locke's claim	45.42	2.94
126	Same, 725 feet west of southwest corner Locke's claim	56.90	5.04
127	Same, 775 feet west of southwest corner Locke's claim	76.40	3.68
128	Same, 850 feet west of southwest corner Locke's claim	62.08	6.65
129	Same, 1,075 feet south of southwest corner Locke's claim	55.22	2.73
130	Water from old hole 40 feet east of point 1,250 feet south of southwest corner Locke's claim	20.87	8.54
131	Salt 1,350 feet south of southwest corner Locke's claim	83.40	4.53
132	Salt 1,250 feet south of southwest corner Locke's claim	40.42	2.06
133	Water from old hole 150 feet east of point 1,150 feet south of southwest corner Locke's claim. From upper (surface) stratum of brine	12.63	6.14
134	Water from corner stratum, same hole	13.04	6.23
135	Salt crust from 5 feet north this hole	68.64	3.39
137	Salt from 2,225 feet south of southwest corner Locke's claim	14.18	1.81
138	Water from old hole 50 feet east-southeast of southwest corner Fox claim	.97	1.16
139	Salt, 900 feet northwest of southwest corner Fox claim	47.18	1.30
140	Salt, 1,375 feet northwest of southwest corner Fox claim	....	....
143	Water from auger hole at location of No. 140	15.74	5.94
144	Salt 315 feet northeast of No. 140	82.46	2.66
145	....	41.34	2.83
146	Same as No. 140	72.06	2.26
148	Salt from east side of first drainage line east of R. R. V. Co. camp	58.22	9.26
149	Salt 100 feet north of No. 148	44.22	6.58
152	Salt 150 feet north of southeast corner Locke's claim	29.80	4.83
153	Water from old hole 675 feet north of southeast corner Locke's claim, upper stratum of the brine	11.62	11.92
154	Water from lower stratum, this hole	10.09	11.78
155	Salt from 580 feet southwest of point 675 feet north of southeast corner Locke's claim	69	10.17
156	Water from hole 100 feet northwest of No. 155	7.86	11.46
157	Water from McDonald spring	.076	....
158	Water from new hole 450 feet southeast of point 1,620 feet southwest from McDonald spring	12.58	5.03
159	Salt crust 5 feet north of this hole	67.92	3.79
162	Salt 879 feet toward McDonald spring from No. 158	48.92	1.48
163	Water from lower brine stratum from old hole 200 feet northwest and 80 feet southwest from No. 158	13.99	5.49
164	Water from old hole 390 feet northeast of No. 163	13.97	5.82
165	Salt from 5 feet east of No. 163	64.62	3.26
166	Salt from 5 feet south of No. 164	76.58	3.42
167	Water from well at R. R. V. Co. camp	.07	....
168	Salt from northwest corner of main flat, 0.25 mile southeast of road at log 4 miles out of R. R. V. Co. camp toward Locke's ranch	41.10	....
171	Water from Black Rock Springs	.04	1.53
175	Water from Hot Creek at bridge at Barndt's house	.07	....
176	Main hot spring at Barndt's	.08	....
177	Water from Hot Creek above Hot Springs at Barndt's. From high ditch	.05	....
178	Water from Warm Springs	.08	....
186	Water from a warm spring about 0.5 mile northeast of Locke's ranch	.05	....
187	Water from well at Horton's house, Blue Eagle	.05	....
188	Water from cold spring at Blue Eagle, 100 yards northwest Horton's house	.05	....
189	Water from warm spring here, 50 yards west of Horton's house	.04	....

TABLE XX.—*Analyses of saline crusts found in Railroad Valley.*

[Parts per 100,000. Analyses by J. A. Cullen.]

No.	Ca.	Mg.	K.	Na.	SO_4.	Cl.	CO_3.	HCO_3.	Total solids.
76	12	6	322	1,509	987	640	600	732	4,808
92	10	4	5,248	24,549	7,800	30,800	2,640	5,856	76,379
96	10	4	5,473	23,799	4,443	34,020	1,800	3,782	73,331
102	10	3	4,105	21,817	3,785	33,040	600	1,342	64,702
154	40	12	987	39,475	555	6,650	None.	31	12,605
Brine	......	......	......	25,475	......	......	......	......	......
155	12	6	5,826	25,475	7,734	38,360	180	427	78,020

76. Salt crust near spring 6 miles south of Locke's claim.
92. Center salt pan at road crossing.
96. East edge draw.
102. Salt pan.
154. Water from lower stratum; water hole southeast corner Locke's claim.
155. Salt from 580 feet southwest of point 675 feet north of southeast corner Locke's claim.

TABLE XXI.—*Analyses of Death Valley brines.*

[Parts per 100,000.]

No.	Ca.	Mg.	K.	Na.	Cl.	SO_4.	CO_3.	HCO_3.	Total solids.
1*a*	57.1	135.6	1,197.7	12,339.4	18,557.5	2,057.0	Tr.	38.0	34,606.4
2*a*	64.3	120.3	913.4	12,389.8	18,557.5	1,978.8	Tr.	38.0	34,138.6
3*a*	71.4	94.0	683.3	12,456.6	18,620.0	1,900.6	Tr.	45.8	34,122.0
4*a*	71.4	133.3	1,361.7	12,426.1	18,620.0	2,324.4	30	45.8	35,057.0
5*a*	92.9	113.7	1,170.0	12,522.3	18,620.0	2,336.8	15	30.5	35,318.0
6*a*	71.4	98.4	1,183.0	12,602.0	18,620.0	2,349.1	30	45.8	35,243.0
7	71.4	63.4	383.6	12,465.9	18,690.0	1,324.7	15	45.8	33,148.0
8	92.9	40.3	349.8	12,442.9	18,830.0	1,053.2	Tr.	30.5	32,817.0
9	85.7	35.2	372.4	12,558.7	18,690.0	1,468.7	Tr.	30.5	33,540.0
Average	79.6	97.6	907.0	12,451.3	18,620.2	1,947.8	22.2	39.9	34,470.0

Sample No. 1*a* taken from hole about 5.5 miles northeast from Eagle Borax Works. (Size of hole 16 feet deep, 2.5 feet long, and 2 feet wide.)

Sample No. 2*a* taken about 6 miles northeast from Eagle Borax Works. (Size of hole 2 feet wide, 2 feet long, 3 feet deep, out on smooth salt 1,000 feet from rough salt.)

Sample No. 3*a* taken 0.5 mile east from sample 2*a*. (Size of hole 2 feet by 2 feet by 3 feet.)

Sample No. 4*a* taken 0.5 mile east of sample No. 3*a*. (Size of hole 2 feet by 2 feet by 3 feet.)

Sample No. 5*a* taken 1 mile north from sample No. 4*a*. (Size of hole 2 feet by 2 feet by 3 feet.)

Sample No. 6*a* taken 0.5 mile west of sample 5*a*. (Size of hole 2 feet by 2 feet by 3 feet.)

Sample No. 7 taken 1 mile north of sample No. 3*a* on smooth salt in hole 10 feet deep, 3 feet wide, 4 feet long.

Sample No. 8 taken from pothole 0.5 mile north of sample No. 7. Depth of hole unknown, but very deep. Four feet in diameter. Only 1 sample marked No. 8. Sample No. 8 taken on rim of rough salt.

Sample No. 9 taken 1 mile north from pothole No. 8 on rough salt. Depth of hole unknown.

Samples taken by J. H. Jones. Analyses by J. A. Cullen.

TABLE XXII.—*Analyses of waters and brines.*

[Samples collected by E. E. Free. Analyses by A. R. Merz.]

No.	Description.	Total solids per 100 c. c.	K_2O in total solids.
			Per cent.
306	Slough at first crossing, road from Furnace Creek to Bennetts Wells	36.51	3.42
307	Water from hole 18 feet deep, 1 mile north of sink (saline pond northeast of Bennetts Wells)	20.36	1.08
326	Surface water from near road from Furnace Creek to Bennetts Wells, 10 miles from Furnace Creek Road	10.42	1.50
327	Water from 10-foot dug hole on this road, 9.7 miles west of Furnace Creek	36.81	3.31
331	Water from 4-foot dug hole at U. S. Geological Survey, B. M. 72, on road from Furnace Creek Ranch to Bennetts Wells	33.80	.96
338	Water from hole in mud flat northwest of Furnace Creek 7,500 feet northwest from land monument at old borax works north of Furnace Creek, hole 2 feet deep	33.28	3.08
339	West side of valley, due west from Furnace Creek Ranch, water from dug hole 3 feet deep	2.77	1.75
341	Water from dug hole 0.25 mile east of No. 339, 2.5 feet deep	15.12	2.38
342	Water from dug hole 0.25 mile east of No. 341, depth 7 feet. On main flat	34.18	2.98
343	Water from surface pool at old bridge due west of Furnace Creek Ranch (Skidoo trail)	32.05	2.25

TABLE XXIII.—*Analyses of muds and clays.*

[Samples collected by E. E. Free. Analyses by A. R. Merz.]

No.	Description.	Total soluble solids.	K_2O in total soluble solids.
		Per cent.	*Per cent.*
316	Death Valley flat, east side, 500 yards west of road, 5.4 miles south of Furnace Creek Ranch, surface salt	22.17	0.39
317	665 feet east of Bennetts Wells, salt from surface of slough bottom	10.65	1.79
319	Clay from 3 feet under surface, 1 mile east of Bennetts Wells	12.16	2.22
320	Clay from shallow hole 0.25 mile east of No. 319	21.49	1.12
323	Water squeezed from clay obtained from hole in slough 1,800 feet east of Bennetts Wells	18.24	3.03
335	Sandy clay, bottom of hole east side of valley on road from Furnace Creek to Bennetts Wells	25.54	2.09

TABLE XXIV.—*Analyses of alkaline Death Valley soils.*

[Parts per 100,000.]

No.	Ca.	Mg.	K.	Na.	SO_4.	Cl.	CO_3.	HCO_3.	Total solid.
20	343	44	193	38,460	823	59,360	None.	122	99,312
21	456	44	438	14,161	2,402	21,000	None.	240	38,678
22	3,200	380	3,316	14,364	13,390	19,740	600	732	55,239
23	257	35	290	37,893	987	58,240	None.	122	97,783
24	229	35	226	38,608	527	59,600	None.	122	99,415

Description:
20. Salt crust from Death Valley 3 to 6 inches thick, opposite Telescope Peak.
21. Clay underlying salt crust. Opposite Telescope Peak.
22. Heaved ground near periphery. Opposite Telescope Peak.
23. Pothole 5 feet in diameter, 10 feet deep. Salt from margin of pothole.
24. Hairlike salt from edge of hole.
Analyses by J. A. Cullen. Samples by G. J. Young.

TABLE XXV.—*Analyses of various samples from Searles deep well.*

No.	Total.		Water soluble.		Insoluble.	
	K.	Na.	K.	Na.	K.	Na.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
209	3.48	4.72	0.23	2.54	3.25	2.18
211	4.26	5.96	.27	4.81	3.99	1.15
212	1.14	29.94	.91	30.34	.23	.0
213	2.64	14.14	.44	11.23	2.20	2.91
214	.46	16.91	.09	8.43	.37	8.48
215	.78	24.05	.26	11.81	.52	12.24
216	3.07	10.21	.42	7.66	2.65	2.55
217	1.58	19.77	.09	12.27	1.49	7.50
218	3.79	7.31	.59	5.28	3.20	2.03
220	2.73	9.95	.42	7.94	2.31	2.01
221	2.30	9.13	.43	7.48	1,87	1.65
222	1.55	6.13	.06	.64	1.49	5.29
223	2.98	5.70	.25	4.64	2.73	1.10
224	1.52	6.51	.28	5.68	1.24	.83
225	2.28	5.31	.20	2.34	2.08	2.97
226	2.79	7.75	.58	5.70	2.21	2.05
227	.98	32.03	.70	31.23	.28	.80
228	1.44	10.28	.48	6.40	.96	3.88
229	4.19	6.36	.33	4.23	3.86	2.13

209. Marked "Deep well, Mar. 9, 1896. Soft clay overlying at hard streak 62.5 feet."

211. Marked "Deep well, Mar. 9, 1896. Clay from bottom of well to date. 227 feet 10 inches. K–S."

212. Marked "Crystal deposited by standing over night from water taken from well at 600 feet. Source of water we presume at 400 feet."

213. Marked "From deep well Sept. 2, 1895, at 409 feet. Depth of deposit 408 to 427 feet."

214. Marked "Crystal at 427 to 442 feet. Drilling hard as rock."

215. Marked "* * * with bed of No. 3. 442 to 469 feet."

216. Marked "Deep well No. 4. 469 to 500 feet."

217. Marked "Green mud with No. 5. Strong ammonia smell from 506 feet. Dec. 31, 1895. Depth of deposit 500 to 515 feet."

218. Marked "Depth of deposit No. 6. 515 to 520 feet."

220. Marked "From 535 feet on Jan. 8, 1896. Depth of Deposit 530 to —— feet. No. 8."

221. Marked "Rimmings from deep well, Borax Lake, at 540 feet. Showing formation in clear parallel lines."

222. Marked "Washings from mud of deep well at 540 feet."

223. Marked "Jan. 13, 1895, from 575 feet."

224. Marked "Jan. 15, 1896, from 580 feet."

225. Marked "Rimmings between 586 and 5*6 feet ***."

226. Marked "Deep well at 600 feet, Mar. 5, 1896."

227. Marked "Crystals from water at 600 feet."

228. Marked "Deep well at 620 feet, Mar. 9, 1896."

229. Marked "Black and gray mud taken from deep well at 627 feet. Black turns gray on exposure."

TABLE XXVI.—*Sodium-potassium ratios for samples from Searles deep well.*

No.	Soluble Na/K.	Insoluble Na/K.	Total Na/K.	No.	Soluble Na/K.	Insoluble Na/K.	Total Na/K.
209	10.9	0.67	1.32	221	17.42	0.88	3.97
211	18.1	.28	1.40	222	11.35	3.54	4.47
212	33.2	.0	26.25	223	18.60	.40	1.91
213	25.75	1.32	5.36	224	20.6	.67	4.28
214	98.0	23.0	36.70	225	11.85	1.43	2.33
215	46.0	23.5	30.75	226	9.73	.93	2.78
216	18.5	.96	3.92	227	44.7	2.86	32.75
217	147.0	5.05	12.5	228	13.5	4.05	7.12
218	8.95	.635	1.93	229	12.8	.55	1.52
220	19.17	.9	3.65				

TABLE XXVII.—*Composition of alkali samples from deep bore in Searles marsh.*

No.	Ca.	Mg.	K.	Na.	Cl.	SO_4.	CO_3.	HCO_3.	Total soluble salts.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
209	0.094	0.020	0.23	2.54	3.47	2.40	Tr.	0.32	9.07
211	Tr.	.010	.27	4.81	5.27	2.79	0.12	.36	13.63
212	Tr.	.008	.91	30.34	10.73	45.14	1.63	2.64	91.40
213	Tr.	.084	.44	11.23	6.36	3.78	3.74	6.59	32.21
214	.038	.221	.09	8.43	2.46	.37	5.34	8.15	25.09
215	Tr.	.192	.26	11.81	3.96	1.08	6.10	12.10	35.49
216	.038	.004	.42	7.66	7.15	5.31	1.16	2.32	23.95
217	.043	.006	.09	12.27	9.37	3.00	3.85	5.05	33.67
218	Tr.	.009	.59	5.28	5.27	3.39	.37	.85	15.76
220	Tr.	.045	.42	7.94	7.57	3.94	1.09	1.76	22.76
221	Tr.	.020	.43	7.48	3.57	1.84	3.61	4.76	21.71
222	Tr.	.004	.06	.64	.45	.21	.15	.34	1.97
223	.108	.015	.25	4.64	4.60	3.56	.15	.31	13.64
224	Tr.	.006	.28	5.68	5.82	3.48	.27	.52	16.06
225	.043	.006	.20	2.34	2.65	1.43	.09	.12	6.88
226	.050	.010	.58	5.70	6.32	3.55	.21	.40	16.82
227	Tr.	.008	.70	31.23	11.94	45.66	1.63	1.96	93.12
228	Tr.	.008	.48	6.40	7.78	2.74	.15	.56	18.12
229	.065	.012	.33	4.23	4.55	2.98	.06	.25	12.48

TABLE XXVIII.—*Composition of soluble salts in samples from deep bore in Searles marsh.*

No.	Ca.	Mg.	K.	Na.	Cl.	SO_4.	CO_3.	HCO_3.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
209	1.04	0.21	2.52	22.93	26.38	20.64	Tr.	3.48
211	Tr.	.07	1.95	34.00	39.76	22.49	0.89	2.61
212	Tr.	.01	1.00	28.17	11.70	54.08	1.77	2.88
213	Tr.	.26	1.35	32.64	19.74	12.76	11.57	20.41
214	.15	.88	.35	33.53	9.80	1.47	21.24	32.45
215	Tr.	.54	.72	33.20	11.17	3.14	17.19	34.13
216	.16	.01	1.74	34.03	29.91	24.34	4.83	9.68
217	.13	.02	.25	35.59	27.84	9.78	11.43	15.00
218	Tr.	.06	3.72	31.38	33.42	23.59	2.31	5.40
220	Tr.	1.97	1.79	33.26	33.24	25.91	4.67	7.72
221	Tr.	1.12	1.97	33.60	16.43	13.30	16.61	21.93
222	Tr.	.15	2.85	31.63	22.93	11.78	7.74	22.91
223	.72	.11	1.83	32.55	33.76	27.55	1.11	2.27
224	Tr.	.04	1.71	33.82	37.19	23.77	1.69	3.25
225	.62	.09	2.87	32.17	38.48	22.67	1.31	1.77
226	.29	.06	3.44	31.85	37.53	23.06	1.26	2.37
227	Tr.	.01	.74	28.56	12.79	53.70	1.74	2.10
228	Tr.	.04	2.62	33.83	42.99	16.61	.83	3.06
229	.52	.09	2.66	32.00	36.98	26.08	.48	1.98

TABLE XXIX.—*Analyses of water and mud from Searles Lake well, Cal.*

[Samples collected by E. E. Free. Analyses made by A. R. Merz].

Description of samples.	Total soluble solids.	K_2O in total soluble solids.
	Per cent.	*Per cent.*
356. A VII, water 20 feet down	42.8	6.08
357. E 5, mud from 40 feet	36.88	1.41
358. E 5, water from bottom, 48 feet	29.98	3.04
359. E 4, water from bottom, 70 feet	25.43	2.06
360. E 4, mud from bottom	35.26	0.50
361. E 3, water from 42½ feet, artesian	29.60	2.88
362. E 3, mud from 75-80 feet	19.86	2,18
363. E 2, water from 60 feet	35.9	2.52
364. E 2, mud from 98 feet	54.80	2.29
365. E 1, water from 100 feet	25.4	1.35
366. E 1, mud 41 feet	49.52	0.46
367. E 2, mud and crystals from 70 feet	60.99	0.516

E 1. Southwest corner section 14, township 26 S., range 43 E.
E 2. Southwest corner section 11, township 26 S., range 43 E.
E 3. Southwest corner section 10, township 26 S., range 43 E.
E 4. Slightly north and east of middle of west line section 10, towsnhip 26 S., range 43 E.
E 5. Slightly north and west of middle of east line, section 17, township 25 S., range 43 E.

TABLE XXX.—*Petrographic examination of samples from Searles deep well.*

[Analyses by J. C. Jones.]

No.	Description.
209	Similar to 221 and 213.
211	Fine-grained tourmaline, biotite, hornblende, plagioclase, and quartz grains recognized. Major part of material clay cemented by gaylussite.
212	Larger grains pirssonite, limonite, a few quartz grains.
213	A fine mud cemented by carbonates with a few fragments of quartz, hornblende, tourmaline, and iron oxide.
214	Crystals of pirssonite with inclusions of clay and iron oxide.
215	Mostly crystals of pirssonite, some halite, grains of quartz, clay, and iron oxides.
216	Pirssonite in broken crystals, limonite, kaolin, biotite, tourmaline, quartz. Fine-grained material average diameter, 0.5 mm.
217	Crystals of pirssonite, nodules of limonite, a few grains of quartz, hornblende, plagioclase.
218	Mostly clay and iron oxide cemented by carbonates; some grains of quartz, hornblende, biotite, and a few clouded and decomposed orthoclase crystals noted.
220	Mostly clay cemented by pirssonite; mineral fragments of quartz, hornblende, tourmaline, biotite, apatite, and many fresh and clouded fragments of microcline, approximately about 25 per cent of the mineral fragments left after washing out clay and dissolving carbonates. This is the only sample in which feldspar crystals approaching freshness were noted.
221	A fine mud firmly cemented by carbonates with a few fragments of quartz, hornblende, and hydrated biotite.
222	Oolitic sand; rounded grains composed of minute grains of quartz cemented in part by carbonates and iron oxide but retaining form after being acted on by acid. Not a true oolite as no concentric structure could be noted.
223	Fine-grained clay grains of quartz, hornblende, biotite, cemented by carbonates.
224	Similar to No. 223.
225	Fine-grained clay, cemented by carbonates, grains of tourmaline, quartz, hornblende, apatite, and biotite.
226	Similar to No. 223.
227	Grains about 1 millimeter in diameter, gaylussite, limonite, quartz.
229	Similar to No. 225.

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